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RESEARCH REPORT

Approaches to Learning by Students in the Biological Sciences: Implications for teaching

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This study is an investigation of the epistemological beliefs and study habits of students undertaking first-year courses in Biological Chemistry and Biochemistry. In particular, we were interested in the relationship between students' epistemological beliefs about learning and knowledge, approaches to learning, and achievement. The study adopted a mixed-methods approach in which quantitative and qualitative data have provided complementary insights into the beliefs and approaches adopted by these students. Our findings indicate that most students tend to adopt beliefs that knowledge and learning involves the accumulation of information and the capacity to reproduce on demand in examinations. Approaches to learning reflect these beliefs and are dominated by rote learning and preference for assessment by examination. Few students adopt strategies that emphasise the relationship of concepts to those already learnt or to applications relevant to biological science. Implications of this study for reform of university teaching practices as well as secondary practices are discussed.

Keywords: *Approaches to Learning; Biological Sciences; Examinations; Learning by Rote*

Introduction

The biological sciences have assumed an important role in the contemporary knowledge economy. Given the rapidly changing knowledge base of biological sciences, graduates need to have substantive understandings of core concepts as well as the capability to accommodate continual change. Hence, to be successful in their chosen careers, students need to develop lifelong learning attributes that contribute to success in post-university life such as skills of complex problem-solving, innovation, and adaptability (Watters, 2000). As a multidisciplinary and transdisciplinary body of

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knowledge (Nowotny, Scott, & Gibbons, 2001), the complexity of the biological sciences requires students to acquire considerable conceptual understanding of topics drawn from a range of traditional disciplines—chemistry, mathematics, physics, and technology—and to display the procedural knowledge and analytical skills necessary to solve complex multi-disciplinary problems (Josefsson, 1987; Zeller, 1994).

Contemporary approaches to teaching in the biological sciences have been critiqued. Information delivered in mass lecture format accompanied by multiple choice examinations establishes a context that fosters learning by memorisation. For example, Hughes and Wood (2003) have drawn upon the "empty vessel" metaphor to describe the nature of biochemistry teaching. They have argued that the student is analogous to a bottle being filled up with information spouted by the lecturer. When the bottle is filled, the student is ready to graduate and be sent out into the world. Unfortunately, they claim that not all of the information is captured by the bottle and furthermore the information contained within the bottle might not be the right information the student needs to solve future problems. The pedagogical approaches based on mass lecture and workshop experiences have remained fundamentally the same for decades despite advances made in other disciplines in curricula; for example, through problem-based learning (Gijselaers, 1996). A considerable number of students, although successful in these situations, struggle with applying their knowledge to meaningful problems. Anecdotal evidence suggests many students are reluctant to engage in alternative learning experiences designed to enhance deeper thinking about content. Hence, contemporary practices force students to adopt particular approaches to learning that are oriented to surface learning and are inappropriate in the context of modern biological science.

Significant research outcomes on contemporary undergraduate biological sciences are limited despite considerable funding (Stokstad, 2001). What exists has tended to emphasize the development of manipulative laboratory skills (Ahmed, 1996), content (Hughes & Wood, 2003), or address issues around class sizes (Adams & Slater, 1998; Krockover, Shepardson, Adams, Eichinger, & Nakhleh, 2002). Given the changing nature of the biological sciences and greater emphasis on integration of knowledge from various domains, research is needed to explore students' approaches to learning. This study documents the relationships between students' beliefs about learning and knowledge (i.e., their epistemological beliefs), and how students engage with learning in foundation biological sciences.

Theoretical Background

This study draws upon an extensive knowledge base in learning in science, but in particular focuses on student beliefs about learning. However, in constructing a theoretical framework we need to acknowledge not only students' beliefs about learning, but also other factors such as the nature of the learning environment, students' prior experiences, and their motivation or goal-setting dispositions.

Learning environment research draws upon constructivist epistemologies, which posit that meaningful learning requires students to engage actively in assimilating new information into existing knowledge structures (Ausubel, 1968; Bruner, 1990; Novak, 1988). According to von Glasersfeld (1990), "cognition serves the subject's organisation of the experiential world, not the discovery of an objective ontological reality" (p. 23). However, Confrey (1990) argued that "we construct our understanding through our experiences, and the character of our experience is influenced profoundly by our cognitive lens" (p. 108). Recognising students' prior experiences and how students come to make sense of these experiences are essential elements establishing effective learning environments. A vast body of research demonstrates students' ideas are often in conflict with the accepted views of science (e.g., Wandersee, Mintzes, & Novak, 1995) and presumably their lecturers'. Students' diverse set of personal experiences including direct observation, media, and language, and teachers' explanations and instructional materials contribute to the formation of mental networks with concepts that are not always organised with propositional relationships congruent with scientific understandings. Indeed, ideas are held in isolation unconnected with other fundamental ideas of science. For many, ideas are valued above relational understanding. The task for science educators is to provide new cognitive lenses and to challenge the utility of their students' pre-existing lenses. In essence, these new lenses provide a perspective that scientific knowledge is constructed through consensus within a discourse practised by participants who share common epistemological beliefs.

At issue in this paper are the beliefs held by students about learning and knowledge and their approaches to learning. An important consideration influencing the quality of student learning relates to their epistemological beliefs about learning and the acquisition of knowledge (Bendixen, Dunkle, & Schraw, 1994). Where research has been conducted it appears that epistemological beliefs may drive the type of information processing the student uses and might subsequently impact how the student engages in an activity (Schreiber & Shinn, 2003) as well as the way they apply their knowledge (Brownlee, 2001). Beliefs about learning and knowledge were explored by a number of pioneering researchers. Perry (1970) described college students' epistemological beliefs as ranging through a hierarchy from dualism to relativism, where dualism represented beliefs that knowledge comprised absolute truths and relativism was that knowledge was personally constructed. In another methodological approach (phenomenography) focusing on the approach to learning, Marton and Säljö (1976) and Säljö (1979) revealed a number of views of learning were held by students, which illustrate a transition from a "surface" to a "deep" approach. In those studies, students described Beliefs about Learning as:

1. Involving a quantitative increase in knowledge—learning is acquiring information or "knowing a lot".
2. Memorizing—learning is storing information that can be reproduced.
3. Acquiring facts, skills and methods that can be retained and used as necessary.
4. Making sense or abstracting meaning—learning involves relating parts of the subject matter to each other and to the real world.
5. Interpreting and understanding reality in a different way—learning involves comprehending the world by re-interpreting knowledge.

Subsequently, in a large number of phenomenographic studies over nearly 30 years, Biggs and his colleagues (Biggs, 1976, 1987, Biggs, Kember, & Leung, 2001) have envisaged students' approach to learning as manifested through three dimensions: Surface (SA), Deep (DA) and Achieving (AA). Students who view learning as the acquisition of knowledge or information as a commodity tend to adopt surface learning approaches, whereas those who see learning as sense-making or comprehension are disposed to adopt deep approaches (Biggs, 1987, 2003). A third approach described as an achieving or strategic approach is adopted by students who seek to get good marks and adopt strategies to achieve these as short-term goals. A motivational factor and a strategic factor exist within each dimension.

Motivation plays a crucial role through its influence on student commitment. The literature on motivation is beyond the scope of this research, but as part of a dynamic interactive system a brief consideration is necessary. Motivation to learn can be driven by a desire to achieve certain goals (Dweck & Leggett, 1988; Eccles & Wigfield, 2002), by a sense of self-efficacy (Bandura, 1977, 1997) in undertaking a learning task, and by a range of psychological factors that impact on students' engagement. For example, Biggs (1987, 2003) argues that motivation to learn could be driven by a *fear of failure* in a surface approach, or interest in *understanding* underpinning a deep approach, or in an achievement approach, a disposition towards *achievement*. Additionally, students adopt strategies ranging from *rote learning* in the case of surface learners, to *maximizing meaning* for deep approaches and effective *use of space and time* for achieving approaches.

In concluding this background, we focus briefly on issues of teaching. Research on effective teaching highlights that there is no one ideal model of teaching, but studies that seek student views identify a number of common factors predominately relating to student centeredness, expert discipline knowledge (Witcher et al. 2003), intellectual excitement and interpersonal rapport (Lowman, 1994), and commitment to facilitating learning in individual students (Moses, 1985). Other research drawing upon theoretical perspectives highlights factors such as reflectivity, pedagogical content knowledge, and capability to encourage deep rather than surface learning and meaningful assessment practices (Ramsden, Margetson, Martin, & Clarke, 1995). From a cognitive perspective, Sternberg (1990) highlights the role of selective encoding of information, selective combination of information in which new information is integrated as propositions, and selective comparison through which the learner focuses on the relationship between new knowledge and prior knowledge.

Traditional didactic approaches and transmissive models seemingly dominate teaching in the biological sciences where delivery of information occurs in lecture format with the extensive reliance of textbooks, and with limited opportunity for student engagement in social learning through which complex ideas are discussed and meaning negotiated (Palincsar, Magnusson, Marano, Ford, & Brown, 1997). Intuitively, this form of teaching attempts to impose a cognitive lens without allowing opportunities for students to engage in sense-making through which they are able to selectively encode, combine, and compare new knowledge.

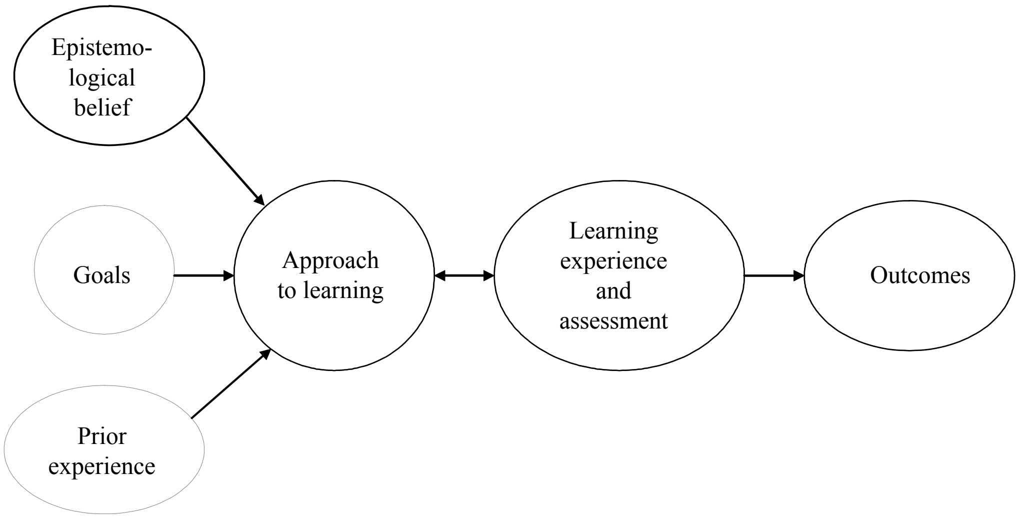

Figure 1. A conceptual framework for learning

The conceptual framework for this study is illustrated diagrammatically in Figure 1. This framework parallels the system described as a Presage–Process–Product model (Biggs, 1987, 1993) that captures learning as a process in which the student characteristics, teaching context, and learning outcomes mutually interact forming a dynamic system. The approach a student adopts to learning is influenced by his or her epistemological beliefs, goals, prior experiences, ability, individual differences in their approaches to learning, and the nature of the material being taught. The process component describes the learning environment, assessment requirements, and other curriculum or pedagogical issues. Dispositions to approach learning either in a deep or surface mode are moderated by the nature of the learning task. The learning experience itself is influenced by the curricular assumptions adopted by course designers and reflects their beliefs about learning and what is valued knowledge in this context. The learning approach is also influenced by the pedagogical skills and competence of the lecturer. Finally, assessment practices will play a moderating role that, if in alignment (Biggs, 1996), should reinforce curricular goals; namely, a rich conceptual understanding of the content.

Aim

The aim of this study was therefore to investigate the approaches to learning adopted by students undertaking studies in first-year Biological Chemistry and Biochemistry as part of several degree programmes in the biological sciences. In particular, we were interested in the relationship between students' approaches to learning, epistemological beliefs about learning and knowledge, and achievement. It is hypothesised that beliefs about the nature of knowledge and learning (known as epistemological beliefs) are related to students' approaches to learning manifested through specific study strategies.

Two research questions guided the study:

1. Is there a correlation between student achievement and their approaches to learning?
2. In what ways do epistemological beliefs students hold about learning impact on approaches to learning in the context of biological science?

Methodology

This study was undertaken at a metropolitan university in Australia. Students participating in this project were enrolled in one of several programmes, including Bachelor of Science, Bachelor of Biomedical Science and Bachelor of Biotechnology programmes. Students are normally required to complete four courses in each semester of study.

In order to capture the complexity of the situation, a mixed-method approach that included both qualitative and quantitative methods was employed within an interpretative framework (Erikson, 1998). One of the authors (D.W.) was the teacher in the course. In pursuing a qualitative approach, the research drew upon interviews to build a complex, holistic picture of participants' experiences in order to describe and explain problematic issues and meaning in individuals' lives (Creswell, 1998). Quantitative data on participants, collected through surveys and performance records, provided convergent information to complement the interview data.

Participants

The study was conducted in Semester 2 with a first-year undergraduate class in Biological Chemistry (class size ~230). Eighty-five students aged 18 or over volunteered to participate in the quantitative aspect of this study. Ten volunteer students were also interviewed during the qualitative phase of the study. Ethical clearance was obtained from the Human Ethics Committee of the university to carry out this study.

Most students in these programmes are required to undertake specialist science courses, namely Biological Chemistry and Biochemistry. Students in the Bachelor of Science programme are also required to undertake a Science Technology and Society course, which takes a sociological perspective on the role of science in contemporary society. Assessment strategies in this course are based on essays, tutorial participation, and exercises undertaken during tutorial sessions. Other students pursue studies in Statistics and Computing along with a wide range of further options. Assessment in the Statistics and Computing course is heavily weighted towards a final examination. Although data were collected during Biological Science classes, approximately 95% of these students were also enrolled in the Biochemistry course. Biological chemistry focuses on elementary organic and inorganic as well as molecular interactions relevant to biological systems, the properties of water, acids and bases, pH and buffers, and elementary bio-energetics. Biochemistry covers content related to DNA and RNA metabolism, protein synthesis, amino acids and protein structure, enzymes, and membranes.

The courses are delivered through 3-week cycles of 4 h of lectures covering two modules in weeks 1 and 2 followed by two workshops covering each module in week 3. These cycles continue through to week 12 followed by a revision week. In addition laboratory classes are held throughout the semester for Biological Chemistry. Lectures tend to adopt a traditional style of delivery of information from the podium using presentation software and animations. The 2-h workshops are based on a series of worksheets written for each module, which are given in the study guide. These are typically designed to reinforce lecture material and encourage students to engage in discussion of the concepts and to apply their knowledge to solving problems that attempt to situate the content in a meaningful real world application. In 2004 (when this study was conducted) budgetary constraints precluded running multiple workshops of 30 students each, thus the workshops were run as "plenary" workshops for the whole class in a large lecture theatre. Thus for these students there was little opportunity for peer discussion. A short multiple choice quiz was given at the end of each workshop as part of continuous assessment.

Students rely on separate textbooks supplemented with study guides to point them to relevant sections of the text. Consideration of assessment strategies is salient to understanding the context of this study. These are outlined in Table 1 and illustrate the emphasis on multiple choice, and short answer quizzes and examination questions. Two assessment items (short answer and multiple choice) similar to those undertaken in workshops are illustrated:

- Short answer: *The pKa for a typical long chain fatty acid is about 5. Explain why long chain fatty acids can form micelles in solutions whose pH is greater than 7, but are insoluble in solutions whose pH is below about 4.* The students should realize that at pH 7 the fatty acid will be ionized and thus have a negatively charged head group, resulting in the formation of micelles since the long hydrophobic chains will tend

Table 1. Assessment strategies adopted in core subjects

Assessment instrument	Biological Chemistry	Biochemistry
Laboratory reports	20	
Workshop quizzes (multiple choice)	12.5	20
Module quizzes (multiple choice)		20
Mid semester exam	25	
End of semester examination (multiple-choice and short-answer problems)	42.5	60

to aggregate together away from water and be shielded by the negatively charged headgroups in contact with the water. At pH 4 the acid group will be protonated and hence have no charge. At this pH the molecule is entirely hydrophobic and will form water-insoluble aggregates. This problem thus requires an understanding of the ionization of weak acids in combination with an understanding of the properties of hydrophobic molecules in water.

- Multiple choice: *Consider an acetate buffer, initially at the same pH as its pKa (4.76). When sodium hydroxide (NaOH) is mixed with this buffer, the:*
  (a) pH remains constant
  (b) pH rises more than if an equal amount of NaOH is added to the acetate buffer initially at pH 6.76
  (c) pH rises more than if an equal amount of NaOH is added to unbuffered water at pH 4.76
  (d) ratio of acetic acid to sodium acetate in the buffer falls
  (e) sodium acetate formed precipitates because it is less soluble than acetic acid.

  This question requires a thorough understand of the principles of buffering.

Data Sources and Data Analysis

Quantitative Data

The revised two-factor version of the Study Process Questionnaire (SPQ), developed by Biggs et al. (2001) was used to identify students' approaches to learning. This instrument, which documents strategies and dispositions to learning practices, was administered at the end of a class, midway during the semester. From these data the class median was established for Deep Approach/Surface Approach (DA/SA) and the subscales Deep Motive/Deep Strategy (DM/DS) and Surface Motive/Surface Strategy (SM/SS) as described by Biggs et al. The characteristics of DA/SA and DM/DS approaches have already been described in the background section of this paper. Class performances recorded as grades on a six-point scale were collated at the conclusion of the course and grade performance averages (GPA) for individual students were obtained from Departmental records for both semesters of study in Year 1. Relationships among variables were conservatively calculated using bivariate correlation procedures using SPSS-X, which generated Spearman coefficients.

Qualitative Data

Beliefs about learning (epistemological beliefs) were obtained by semi-structured interviews ranging from 30 to 90 min. The interview protocol was based on open-ended questions that probed student beliefs about knowledge, knowing and learning, motivation, goal setting, approaches to learning, and the nature of their experiences in the course. An interview guide that lists the broad questions and issues that were explored in the interview was used "to ensure the same basic lines of enquiry are followed" (Patton, 2002, p. 343). The concurrent verbal and retrospective debriefing protocols were used (Taylor & Dionne, 2000), mindful of the guidelines suggested by Ashworth and Lucas (2001) for the conduct of such studies.

The interviews were recorded and subsequently transcribed. Data were progressively reviewed and analysed iteratively by the researchers independently, who then discussed common themes and issues. Thus patterns were identified using constant comparative strategies (Strauss & Corbin, 1990) to support or refute hypotheses and to describe and explain important factors that contributed to student engagement and beliefs.

Results

In reporting results in this study we first address Research Question 1 concerning the relationships between approaches to learning as manifested in SPQ scores and achievement. These results confirm a relationship between approaches to learning and achievement. Second we address Research Question 2 by presenting an analysis of interviews with selected students, which highlights their beliefs about knowledge and learning and elaborates on the strategies used.

Correlation of Achievement with Approach to Learning

An analysis of the whole cohort's SPQ scores and relationship to achievement was measured by overall GPA for the first semester (GPA-S1) and the second semester (GPA-S2). Achievement in Biochemistry, Biological Chemistry, Statistics and Computing (Stats) and Science Technology and Society (STS) is presented in Table 2. The table illustrates in each diagonal cell the mean scores and standard deviations on the relevant SPQ subscales (DM, DS, SM or SA), and grade scores expressed as modes. Also shown in each diagonal cell is the Spearman correlation between variables. The class means identified in this study for the subscales of the SPQ agree remarkably well with a study by Skogsberg and Clump (2003) on lower-level biology major students in Idaho (DM 14.5, 4.0; DS 13.4, 4.2; SM 11.8 3.7; SS 13.8, 3.9), in which it was found that psychology students scored significantly higher than biology students on the deep approach, motive and strategy scales. There was little difference in the surface scales.

Examination of Spearman correlations reveals strongly negative correlations ($p < .01$) between Surface Approaches and scores on Biochemistry, Biological Chemistry, Statistics and Computing, and overall GPA. In contrast, Deep Strategies (DS) scores are positively correlated with Biological Chemistry, Biochemistry, and overall GPA but not with Statistics and Computing. These findings suggest that students who achieved well on Biochemistry and Biological Chemistry approached their study driven by a motivation to understand and adopted appropriate strategies to achieve this understanding. These strategies can be understood by considering the questions on the SPQ instrument that loaded on particular scales. Students who scored high on Surface Motive (SM) scale responded strongly to questions on the SPQ instrument, such as "I am discouraged by a poor mark on a test and worry

Table 2. Spearman correlations between SPQ scales, subject achievements and GPA

	DM	DS	SM	SS	GPA S1	GPA S2	Biochemistry	Biological Chemistry	Statistics	STS
DM	14.17 (3.17)									
DS	0.44**	13.65 (2.7)								
SM	–0.31**	–0.19	11.2 (3.9)							
SS	–0.23*	–0.13	0.66**	14.3 (3.8)						
GPA S1	0.11	0.24*	–0.47**	–0.43**	5					
GPA S2	0.11	0.23*	–0.46**	–0.41**	0.70**	5				
Biochemistry	0.10	0.32**	–0.41**	–0.35**	0.78**	0.76**	4			
Biological Chemistry	0.02	0.25*	–0.29**	–0.32**	0.57**	0.72**	0.64**	4		
Statistics	0.10	0.10	–0.46**	–0.48**	0.60**	0.76**	0.43**	0.49	4	
STS	0.04	0.16	–0.12	–0.08	–0.01	0.31	0.21	0.23	0.06	4

Notes: Means (standard deviations) exhibited on the diagonal. Modes exhibited for grade scores. ** $p < .01$ level (two-tailed), * $p < .05$ level (two-tailed). Listwise $n = 69$.

about how I will do on the next test", and those who scored high on Surface Strategy (SS) responded strongly to "I learn best from lecturers who work from carefully prepared notes and outline major points neatly on the blackboard." The types of question that illustrate a Deep Motivation (DM) include, for example, "I find at times studying gives me a feeling of deep personal satisfaction" or "I believe strongly that my main aim in life is to discover my own philosophy and belief system and to act strictly in accordance with it." Questions loading on Deep Strategy (DS) include "while I am studying, I often think of real life situations to which the material that I am learning would be useful" or "I find most new topics interesting and often spend extra time trying to obtain more information about them". Clearly those students who approached learning with a long-term visionary goal of increasing their understanding and valuing knowledge for its own sake demonstrated higher achievement levels given the nature of the assessment in these subjects.

These findings are consistent with those of Hall, Bolen, Gupton, and Juhl (1995), who found that the achieving "approach" significantly predicted GPA especially in higher ability students as measured by SAT, but are at variance with her observation that deep achieving approaches are also correlated with GPA (Hall, 2001). Interestingly, no correlations are revealed with performance in the Science Technology and Society course.

Student Beliefs about Learning

In this section we analyse data that inform about how students' epistemological beliefs about learning impact on their approaches to learning. Ten students volunteered to be interviewed. Profiles of these students' scores on SPQ are presented first, followed by an analysis of their beliefs about learning.

The profile of SPQ scores on the major scales of DA and SA for these students is shown in Figure 2 and their scores on the subscales of SPQ (SM, SS, DM, DS) presented in Table 3. Aggregate achievement scores (GPA) and achievement grades for Biochemistry and Biological Chemistry for Semester 2 are also provided in Table 3. As seen from Figure 2, most of these students demonstrated somewhat skewed scores with above the mean on one scale and at or below the mean on the other scale. Six students in the present study (Ben, Felicity, Geoff, Candice, Mary, and Theresa) scored higher on Deeper Approach than the mean for the full cohort, while three students (Nikki, Steven, and Dorothy) scored higher by more than one standard deviation on the Surface Approach. The students' names are pseudonyms. This diagram illustrates that these students, with the exception of Geoff, tend to be exclusively either surface learners or deep learners.

Of the students interviewed, only Geoff and Ben had scored substantially higher than the class mean (>1 SD) on the DM scale and Candice, Felicity, and Ben on the DS scale. On the SM scale only Nikki was significantly high. Anna, Ben, Felicity, and Theresa were significantly low on SM, as was Ben on the SS scale. In probing students' beliefs through interviews, we were attempting to examine the relationship between SPQ scores and the approaches used by students in this context. We now

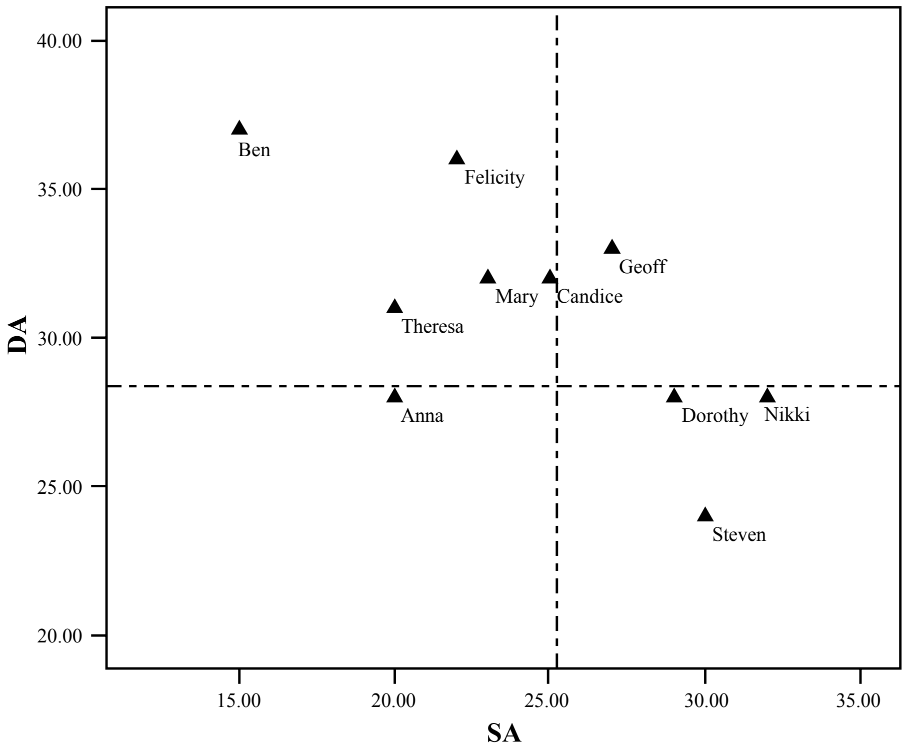

Figure 2. SPQ profile of interviewed participants. Dotted lines indicate class means on the full DA and SA scales

describe the range of *beliefs about learning* and the *approaches or strategies used* by students in learning, and finally beliefs about *assessment*.

Beliefs about learning. Students articulated beliefs about learning that echo the hierarchical categories identified by Säljö (1979) and others (Ramsden, 1992); namely, that successful learning involves "memory", "remembering", "familiarity", or "it becoming second nature". Transcripts were read and themes emerged indicating students' approaches to learning, motivation and beliefs about learning. These themes are summarised in Table 3. In column 3, approaches are described as summary statements or direct quotes from the students. Similarly in column 4 motivational attributions are described, and in column 5 a mapping of beliefs about learning with Säljö (1979) categories is provided based on interpretation of students' utterances.

Interpretation of most students' discussion implies that understanding is objectified as "knowing about". Students focus on the acquisition of information about concepts and validating their knowledge by comparison with other students or textbooks. Few students talked about using knowledge or learning as demonstrating

Table 3. Beliefs about learning, SPQ data and learning outcomes for interviewed students

					Deep Approach		Surface Approach		Grade (seven-point scale)			
Name	Age (years)	Stated approach to learning	Motivation	BAL	DM	DS	SM	SS	Biological Chemistry	Biochemistry	GPA Semester 1	GPA Semester 2
Mary	42	"Learning is delivery"—memory	Intrinsic interest in learning	1–2	17	15	11	12	5.00	5.00	5.00	4.88
Anna	19	Uses diagrams but not systematic	No clear goals	4	15	13	8	12	5.00	5.00	5.00	5.00
Candice	19	"Memorisation is necessary but understanding desirable"	Motivated by altruism to solve health problems/ performance	3	15	17	11	14	5.00	4.00	n/a[a]	4.5
Dorothy	28	Studies by reading widely	Motivated by mastery and driven by a desire 'to understand'	1	14	14	14	15	4.00	4.00	5.00	3.67
Nikki	20	Applies an explicit learnt learning strategy	Motivated by mastery and desire to "find out"	1	14	14	16	16	7.00	6.00	n/a[a]	6.25
Theresa	18	Applies an explicit learnt learning strategy	Motivated by determination	4	15	16	7	13	6.00	7.00	6.50	6.5
Geoff	18	Studies by reading lecture notes	Performance-oriented learning enough "to pass"	1–2	19	14	15	12	4.00	4.00	5.25	4.5
Ben	35	Seeks to understand and then memorises	Motivated by interest to understand	4	20	17	6	9	5.00	6.00	6.25	5.5
Steven	18	Uses memorisation but with understanding	Motivated by desire to be a medical practitioner	1–2	13	11	15	15	5.00	3.00	n/a.	4.5
Felicity	32	Has a strategy that relies on memorisation	Desire to be a forensic scientist—mastery of knowledge	4	17	19	9	13	6.00	6.00	6.25	5.25

Note: BAL, beliefs about learning (Saljo, 1979). [a]Enrollment commenced Semester 2.

outcomes that enable the solution of problems. Reinforcement of this perception is seen in some students' responses that describe understanding as affirmed by feedback, either from examination papers, friends, or self-interrogation. For example Dorothy, whose approach was identified as oriented towards being a Surface Learner with a relatively high SA and average DA, described her beliefs about learning: "I always talk to other people and if they have got similar ideas then I know I am on the right track".

A small number of students highlighted a belief that learning required ideas to be linked to make sense of broader phenomena. For example Theresa, in response to a question on how she knew if she knew something, responded:

> In Biol Chem, we did glycolysis and with the free energy it made so much more sense with what was happening to ATP, why it was going in and why it was going out, so it helps me to remember, because it is hard just memorising without understanding what it means.

Knowledge for her was being able to extract meaning, and to reinterpret old ideas with new explanations.

Some students exhibited strategic and reasoned beliefs about learning based on test performance. Anna, a student whose approach score is average on DA but low on SA, believes that successful performance in tests confirms her understanding of a topic. She is enthusiastic and presumably her approaches are affirmed by her success. Ben, in a similar way, builds confidence through strategies that rely on successful test performance. It would appear that success on tests is not their ultimate goal but considered as a reliable indicator of their understanding of the concepts.

> Anna: Like if you haven't learnt something properly; if you are still doubting yourself and like testing just doing practice tests. I love doing those because that way I know I am learning something and I'll know.
>
> Ben: When I go through all the questions I find another lot of questions anywhere look up books or maybe on the net or something and I ask myself questions and if I am able to answer all of them then I know that I have a good understanding of the subject or the topic.

Although holding beliefs about learning as accumulation of information, some students were highly self-regulatory about their approaches. For example, Candice acknowledged that at university it is the student's responsibility to learn, because "there is nobody going to push me". Learning was described as "researching new things" and "mastering concepts of whatever you need to get to do, in order to get where you are going". Although she expressed a mastery orientation, "I prefer first to try and understand it", she succumbed to a performance orientation as indicated in the following reflection:

> Actually it depends on when the exam [is]. Should I be able to understand it before the exam then that's fine. And I'll work but I prefer to research not just read one textbook, (I) read various textbooks. … It sticks to your mind more and you get more information that way. Or if the exam is quite near then I have to memorise it.

Some students did describe understanding as a form of internal speech: "I can put it into my own words …" (Geoff), "when you go to sleep it sort of plays upon your mind … it becomes second nature" (Steven), and "it's like speaking a second language, you don't have to think about it". These students articulate a position where knowledge is internalised but still conceive of understanding in relation to the accumulation of information. Another described the capacity to teach a concept as indicative of understanding (Felicity, high DA). However, in describing understanding in these terms, she is clearly attempting to relate new information to existing knowledge structures indicative of establishing effective propositional relationships (Anderson, 1983).

> Felicity: um … learning is finding about things you don't know about, understanding it and putting it into context that means something to you so you can relate to it.
>
> Anna: Understanding is making connections. So I try and like, what I try and see is the big picture, because that's what it is. To understand it is to see the big picture, where this has to do with that etc. etc. I just try and do that, and sometimes yes, I prefer not to go to the textbooks because I do think they confuse me sometimes but I more likely go toward friends and people in the course.

Anna and Dorothy were two students who talked in terms of wanting to see relationships between what was being learnt and more general concepts. Dorothy in particular was unconcerned about grades as long as she understood, "grades are not important as long as I pass and I understand". To her, learning was interest driven, about finding out and knowledge about making sense. Although her scores on the SPQ indicate a relative orientation to surface approaches, this comment suggests a deep motivation by attempting to understand how new knowledge explains a socially relevant concept, namely the use of DNA.

> I don't like not knowing something, so I'll try and find any way to find out what it is that I don't know. So if I read an article and I don't understand that, I can't just like leave it at that. I have to then try and work out what it is that I don't understand and then try and work out how to understand it. Because there is so much I suppose about DNA in society nowadays, it's such a big deal I want to understand how it works, what it is that so many people are against certain things, like why they are against, things like that.

She was one of the few students who described understanding in terms of using knowledge to solve complex problems, or awareness that procedural knowledge that might emerge in professional situations after graduation was important. However, as noted in the following, Dorothy did not possess effective learning strategies.

Only one student described a belief about learning as doing something that might be applicable to real-life situations. This student, a Deep Approach-oriented student, emphasises active learning:

> Theresa: workshops are really handy because then you are actually doing, using the information that you have learned and doing questions about it so you can see it in a situation that might happen.

Learning strategies. Students expressed a range of learning strategies. For example Mary, whose SPQ scores indicated she should have Deep Approaches revealed a preference for memorisation:

> lectures are the go … I just enjoy sitting in class and have someone else feed me the knowledge with a spoon… there is just a lot of straight knowledge that you just absorb and memorise I think.

However, Steven's comments were in harmony with his orientation towards Surface Approaches: "learning is just the process of studying and trying to understand the content in the textbook".

These utterances are consistent with a dualistic view that knowledge is comprised of absolute truths (right/wrong) that can be transmitted from experts (Perry, 1970). However, in Mary's case the comments are inconsistent with her SPQ scores.

Anna was confident that she had effective learning strategies, and described her approach in detail as one based on using diagrams, pictures, and flow charts to show connections between ideas. However, even using these strategies she expressed difficulty in making sense of the material. For example, she claimed that she engaged with the text material and made summaries:

> I do know how I learn. If I want to learn something I do diagrams, pictures, I do flow charts to show me how things connect. With that it is just all there and I can't see where the connections are and I have to try and find them and I don't always make the right connections because I don't understand exactly.

High-achieving students made several comments that were consistent with a mastery orientation, and appear to have explicit study strategies. For example, Theresa described her approach to learning in terms of reading and memorising:

> I would try and understand everything that I was learning. … Firstly I would read through it and take notes. [I would] look at topic headlines and try and write down what I could remember from that. Then, I'd go over and see what I had forgotten and then done [*sic*] practice problems and stuff like that… At first you had to memorise the basics, but then as you learn more it sort of melds in together. That's what I am finding at uni; that when I learn more I don't have to memorise it because I understand it. So it's easier to remember. … Just understand everything and not just memorise it because when I understand it gets easier to remember it.

Nikki revealed a highly metacognitive strategy for learning despite an SPQ score indicating a preference for Surface Approaches. She acknowledged that studying for examinations was different from studying to "keep up". In studying for examinations she claimed she was highly focused. She reflected on her regular approach and appears to follow the strategy learnt in school. She "tries to do the whole survey, the questions, read with a purpose and after that I read the text and try to find questions, [and] discuss [them] if I can". For her this was difficult because she finds learning by reading problematic and so she has to be disciplined about reading:

> It comes down to being disciplined since we don't have a test every other week to remind me that I have to read. So it takes like me telling myself that I have to read.

Nikki, who had previously been unsuccessful in other tertiary studies, realised that she needed to have effective strategies, which suggested that learning required engagement with the content:

> Here it is not about really working extra hard but working wisely [and] really looking at [the difference] between recommended and required reading, but just actually getting to know the concepts. [It's about] finding time to really study, understand, and not being left behind and then try to catch up for the exam.

Nikki argued that it was important to "see things", and hence she would regularly attend lectures and use a range of approaches including ICT to get an overview of the concept.

> I find that, if I attend the lecture even if I haven't read for the lecture before and I attend the lecture, when I get out of there and start to look at the material again it doesn't look so new. It's not so striking and it's more easier (sic) for me to understand it. I also like going on the web and finding information there like especially the slides you put up for enzymes for those topics for those modules. I liked that a lot because reading the textbook sometimes becomes monotonous and just you have to force yourself to open the book; but when it's there, you click. It's more interactive like you're not just sitting and you're reading and you can see the graphs in the background.

Felicity was also strategic in her approach to learning but emphasized memorisation. She had commented on the importance of memorisation for success in high school studies and acknowledged that she was "better at memorisation than problem solving". When queried about her specific strategy, she emphasised reading, remembering, and practising problems from past examination papers or from the end of each chapter. Felicity's SPQ score on Deep Strategy was among the highest in the cohort despite a strong orientation towards memorisation. Her preference was for multiple-choice questions in assessment tasks, although when confronted with assignments or problems she stated that she sought help from friends and attempted to establish successful strategies used on easier problems before tackling more difficult ones:

> I ask some people that are in the class with me if they have managed to do it and if they have ask how they did it and see if I can follow it. There's usually answers to some of the ones in the book or if not then go back a stage to the exercise before. You know like to make sure I understand each step along the way like if there's a harder problem I'll go back to the easier ones, before to check that I have got the method right and then try again.

Some students, for example Candice, acknowledged they adopted inefficient strategies that drew upon memorisation and reading:

> Sometimes I sit for a long time reading but then I am actually no longer reading. I would make sure I read for 4 hours straight, but my concentration span, which for me is probably only 30 minutes, [and so] I switch off, and I start daydreaming. I used to sit there and think, the longer I sit here, the more I go through this, the more I will be able to answer questions.

Although she displayed aspects of metacognitive awareness of her learning, she was unable to develop more efficient strategies. The prime goal of the task was to accumulate information to answer questions.

In study techniques and preparing for examinations, there was heavy emphasis placed by students on past examination papers and memorising the study guide.

> Felicity: I learn best from writing things out so for memorising things.
> Candice: Well basically I go through a lot of past papers.
> Steven: I used to cram a lot but I can't say that it was very effective.

When questioned about what they would do if they could not solve a problem, most students replied that they would ask a friend for help, only a few indicating that they would approach the lecturer, and then usually as a last resort. If the friends were unable to assist, some students responded that they would just memorise it (Candice) or forget about it and hope that it was not on the examination (Candice and Geoff).

Dorothy argued that achievement in science is a result of innate ability and acknowledged that, although she likes science, she has to "keep concentrating and keep working, it's not something that I automatically get". Keeping abreast of the course was an important strategy she developed:

> I find the reading is a really important thing if you do the reading, it really helps to understand the lectures, and then to remember it all because if you don't remember the first part by the time you get to the end it doesn't make any sense.

Dorothy's reading, however, tended to be limited to course notes and set material.

Assessment. Given a choice between assignment or problem-solving tasks and examinations, most students stated a preference for examinations. In many instances this preference was associated with the access to strategies such as revising past papers, synthesising lecture notes, textbooks or guides, and memorising. Perceptions also existed that examinations were more authentic because they tested depth of knowledge. For example, Ben favoured examinations because "we would have to have a very good understanding of the concepts to be able to reproduce all of it for the exam". Ben's beliefs about learning indicated the need for deep understanding of concepts but that testing was an efficient mechanism for assessing that learning. These beliefs would be consistent with an orientation to master the content matter rather than to necessarily perform on tests for the sake of grades.

Geoff's approach to assignments and examinations also reflected a focus on understanding but he placed more emphasis on performance. He described assignments as useful for learning about something in particular but that examinations are preferred because they indicate overall understanding and achievement. It was important to Geoff to keep his GPA high by achieving maximum grades.

Steven contrasted his approach to assignments and examinations. The former he claimed involved "active learning", whereas the latter involves remembering and getting information to "stick in your mind". Assignments allowed him to work with other students and build knowledge by "looking over each other's stuff and get ideas from other people". Steven admitted he was not a dedicated student but was able to pass examinations without a great deal of study because of his "photographic memory".

Theresa also acknowledged the value of assignments because they allowed the student to explore a topic in depth and provide opportunities for learning “a lot of detail”. In contrast, she stated that examinations “go over everything”, reiterating the common view that understanding in this course involved accumulation of a body of knowledge.

Limitations

A limitation of this research was the use of the revised version of SPQ, which did not allow exploration of achieving approaches identified in the more developed instrument (Biggs, 1987). The study did not accommodate the background of students in terms of high school experiences, school leavers vs mature age, gender, or other attributes. For example, the existing knowledge base appeared diverse, with some students being able to draw upon previous formal biological science classes in high school whereas others had no formal experience of the discipline. Mature-age students often had wider life experiences or careers of relevance to biological science to draw upon. Most students were motivated by extrinsic factors. Some were highly committed to a career for altruistic reasons (e.g., medicine). For others, long-term goals seemed of little importance. Some students in these courses are seeking a premedical qualification, others will not pursue biological sciences further, and some will continue advanced studies in related science areas. The number of participants did not permit exploration of the influence of long-term goals. The research also focuses on students in their first year at university in a foundation course. Longer term studies are needed to identify whether students’ approaches change as they progress through their courses.

Discussion and Conclusions

This study set out to investigate the relationship between students’ approaches to learning, epistemological beliefs about learning and knowledge, and achievement.

Research Question 1 explored the strength of the relationship between approaches to learning and achievement. Statistically there is a correlation between student approach to learning as measured on the SPQ instrument achievement and their achievement in the courses. Students who were identified as adopting a deep approach generally performed better on examinations. Furthermore, surface approaches were negatively correlated with achievement. These findings were consistent across both biological chemistry and biochemistry courses. The context in which this finding is revealed involves students being required to engage in authentic problem-solving. Throughout the semester workshop activities, although they may have been presented in non-ideal situations, nevertheless required students to engage in more authentic problem-solving activities. These types of problems were incorporated into the final examination. The strength of the relationship suggests that the nature of the learning tasks challenged students to go beyond rote learning strategies and to adopt deeper approaches to learning.

Research Question 2 sought to understand the variety of approaches students used in the study of biological science. On one hand, epistemological beliefs about learning, approaches to learning, and assessment practices were consistent and reflected a traditionalist approach perhaps captured by the frequently stated student preference for large lecture format, dictated notes, memorisation, and regurgitation of facts. Beliefs about learning gleaned through interviews revealed that many students hold a highly dualist perspective that knowledge is comprised of absolute truths (right/wrong) that can be transmitted from experts and that learning involves the accumulation of this information for the immediate goal of passing the examination (Perry, 1970; Schreiber & Shinn, 2003). These findings are consistent with those previously reported (Hughes & Wood, 2003).

However, there was variation in epistemological beliefs about learning, which did influence approaches to learning. High-performing students such as Theresa and Nikki adopted learning strategies that linked new ideas with existing knowledge structures and experiences. They also expressed beliefs about learning and knowledge that reflected sense-making and relationships. Students such as Felicity and Anna also highlighted the relevance and connectedness of ideas. For Felicity, putting new learning into context was an important aspect of understanding. These beliefs are consistent with the more relational views of knowledge revealed in the phenomenograhical studies of Marton and Säljö (1976). However, there was limited evidence of students engaging actively with ideas and each other to construct understanding that was connected to real-life experiences.

Most students described approaches to learning or learning strategies that emphasized rote learning and memorisation. Some, such as Candice, used approaches that they acknowledged were inefficient. Others attempted to use techniques based on rewriting notes or preparing drawings but mostly reliant on set reading material. A few sought to extend their understanding by reading beyond the course material. Several of the interviewed students, for example Anna and Geoff, adopted ineffective rote learning strategies to achieve short-term goals such as examination success. Those such as Nikki and Theresa who were able to draw upon previous experiences, where they were taught study skills, were apparently highly successful. Although probed in the interviews, few students could recall having been taught effective problem-solving skills or learning strategies. Other students, including Ben and Felicity, expressed greater desire to understand fundamental ideas and were successful within this learning environment. These findings highlight the strong relationship between epistemological beliefs about learning as articulated in student discussions, approaches to learning as identified by the SPQ instrument, and performance in examinations based on complex problem-solving.

Beliefs about assessment reinforced an orientation towards knowledge as the acquisition and regurgitation of information. Although a small number of students valued assignment or project work because it allowed for depth of understanding, most saw examinations as authentic indicators of understanding. The importance of examinations sits in stark contrast with the Science Technology and Society course undertaken by students where interactive learning sessions were the norm. Few opportunities existed in Biochemistry and Biological Chemistry courses to foster social learning through interactive tutorials (Palincsar et al., 1997) and to engage students in the cultural discourses of science (Lemke, 1990). Budgetary constraints meant that workshops were run by lecturers as tutorials in which students had little opportunity to discuss problems. The lecturer expected students would come to the workshop having attempted the problems, and being prepared to share strategies. However very few students did this, and those who did reported a reluctance to speak out in such large groups. The majority of students would attend with the intention of copying the strategies outlined by the lecturer. Learning appears for many of these students to be a solitary experience.

The focus in these courses was on content learning and providing the core conceptual frameworks underpinning Biochemistry and Biological Chemistry. However, there is a strong expectation that students can apply their understandings to meaningful problems. Instructional practices involved lecture information delivery and considerable reading and short problem-solving tasks on the part of students. Students were highly accepting of this approach and rarely seemed to challenge lecturers or tutors about the information provided. Indeed, few would approach lecturers to seek clarification and few attempts were reported where new information was connected to existing knowledge as might occur in conceptual change teaching (Hewson, Beeth, & Thorley, 1998). This orientation towards acceptance of information was evident in interviews when students discussed what they did when textbooks provided incorrect or conflicting information. The response was generally to seek arbitration from the lecturer as to "which is right" rather than making any attempt to understand why differing information might be presented.

Implications for Teaching

In foundation courses, students are often in their first year of study, have widely varying backgrounds and characteristics, and have established approaches to learning that have been successful in getting them to where they are. Biological science is complex and the knowledge base is changing rapidly, necessitating students who possess not just a basic knowledge but the capacity to use that knowledge and to become flexible learners. There are four implications emerging from this study.

Firstly, student epistemological beliefs are strongly oriented towards a philosophy that learning involves the accumulation of knowledge that is functional in solving routine-type problems. Approaches to learning are by and large of a surface nature, and students' prime goals in participating in the course are to pass examinations. The common mode of study is memorising questions from past examination papers and those in the study guide. Even where the questions were of a complex nature designed to challenge students' capacity to use information in authentic ways (Shepard, 2000), the ability to transfer their reported success on solving these problems during their course to success in a final examination appears limited. In this study it became apparent that students spend hours memorising information and minor details, and display little ability to make use of the information. Although core conceptual ideas are important, students perceive that they need to know a lot of content to be effective learners. This is a perception that teaching staff need to challenge by emphasising the problem-solving skills or procedural knowledge.

Secondly, students have diverse backgrounds and previous educational experiences. The age range is broad and the recent formal school experience is limited for some students. Irrespective of these backgrounds, few acknowledged experiences in schooling that engaged them in problem-solving tasks that would encourage deep learning approaches. Strategic support to develop effective learning skills or enabling strategies is paramount. Although these are commonly offered to students in orientation programmes, unless they are offered in context they appear to be of limited value. Provision of study support programmes devoted to teaching students how to learn and delivered within the discipline area have proven successful (Durkin & Main, 2002; McGuire, 2004; Zeegers & Martin, 2001).

Thirdly, in order to understand new material the activation of pre-existing knowledge is critical. The student needs to reconcile existing beliefs with the new experiences. If the models and ideas held by the student are inappropriate then conceptual change has to occur (Hewson et al., 1998). Deep understanding is the fundamental goal of science teaching, and this requires the knowledge to be integrated and relational; in other words, ideas are linked to other ideas in a coherent framework. Some students recognised the importance of making connections between ideas. Thus, instructional procedures are necessary that enable learners to engage with new phenomena and to explicitly discover and evaluate their existing models. Ideally, these approaches require a learning environment characterised by discussion, exchange of ideas and engagement in scientific discourses. Teaching approaches need to encourage questioning, clarifying ideas, summarising understandings, and predicting outcomes of specific phenomena.

Fourthly, reflection on teaching requires useful tools to inform practitioners. Biggs et al. (2001) has argued that the concept of SPQ norms may no longer be appropriate given the considerable changes in the higher education sector and that SPQ values may be best served as a means of monitoring students' approaches to learning in a given teaching and learning context and in response to teaching approaches and study tasks (Zeegers & Martin, 2001). In the present study, although a trend was found in the SPQ data indicating that those with a deeper approach to learning were more likely to achieve highly on overall assessment in the biological sciences, there were considerable individual differences reflecting complex motivations and beliefs. The most salient outcome was the emphasis that students placed on learning by rote; but even in the context where rote learning appears to be valued, those students who by SPQ data adopted deep approaches were more likely to achieve. Deep learning in this context appears to involve the adoption of efficient strategies that enable students to engage with the concepts and at the same time resort to memorisation strategies.

If educational practices in biological science courses are to align with reform efforts, there needs to be acknowledgment of the range of beliefs and approaches to learning displayed by undergraduate students in this domain. Essential to reforming practices in biological science is a recognition that change needs to occur, not only at tertiary level, but also at secondary level where the genesis of students' attitudes and beliefs about learning occurs. Establishing authentic learning environments in which the intellectual demands are consistent with the intellectual demands of the environment for which we are preparing the learner is paramount to engaging students in deep learning (Honebein, Duffy, & Fishman, 1993).

The recommended curriculum by the American Society for Biochemistry and Molecular Biology includes a considerable emphasis on research projects (Voet et al., 2003). This implies the adoption of inquiry approaches in which authentic problems are provided that require students to engage in practices analogous to the type of tasks they might be required to do as novice graduates. These approaches are consistent with reform in science education at all levels but require radical changes to contemporary practices (e.g., Yager, 2000). To achieve these goals, a better understanding of how biological science students approach learning and their beliefs about learning is needed.

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