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REINFORCING CONSTRUCTIVIST TEACHING IN ADVANCED LEVEL BIOCHEMISTRY THROUGH THE INTRODUCTION OF CASE-BASED LEARNING ACTIVITIES

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Abstract

In the process of curriculum development, I have integrated a constructivist teaching strategy into an advanced-level biochemistry teaching unit. Specifically, I have introduced case-based learning activities into the teaching/learning framework. These case-based learning activities were designed to develop problem-solving skills, consolidate student learning and understanding, and establish an alignment between major theoretical and conceptual learning material, practical experiences and the assessment items. The evidence presented from student surveys and interviews shows that students perceive that this approach enables the development of problem-solving skills and confirms that students identify a high degree of alignment between teaching and learning activities and assessment. Furthermore, the findings strongly establish that a case-based learning paradigm can facilitate constructive alignment of teaching and learning activities with assessment, and that this approach supports and bolsters student satisfaction and leads to improved student academic performance.

Keywords

case-based learning, active learning, constructive alignment, curriculum development.

Introduction

The project described in this paper advances a constructivist learning strategy and alignment between learning and teaching activities and assessment within an advanced level biochemistry unit. Specifically, this alignment was facilitated through the introduction of case-based learning tasks that promote active student learning, and augment the acquisition of team working, communication and problem-solving skills.

Tertiary teaching in science, technology, engineering and mathematics (STEM) disciplines has tended to be less focused on educational theory, doctrines and philosophy of teaching and learning and more focused on the specific scientific theory and doctrines of the individual scientific disciplines. Tertiary-level academics in many STEM disciplines prioritise their efforts towards keeping up with specific developments in their discipline area and contributing to these developments through research. In fact, research excellence is frequently (and increasingly) the determining factor in Faculty appointments in STEM disciplines. There is a propensity to accept that teaching competence and skills will be something that will be learned and applied ‘on the job’. The development of effective teaching expertise for many tertiary science educators may be borne from the fruits of many years of labour and gradual appreciation and development of good teaching practices through reflective and self-directed processes. In the face of this tradition, it has been argued that tertiary academics have an explicit responsibility to engage themselves in the 'scholarship of teaching' (Boyer, 1990). The reality of the situation is that tertiary academics must acknowledge their dual responsibilities of contributing to research within their specific discipline and engaging in scholarly teaching.

It is widely acknowledged that students learn more effectively if they are *active* rather than *passive* during the learning process. Active participation in the learning process can stimulate 'deep learning' and high-level engagement in contrast to 'shallow learning' and low-level engagement (Marton & Säljö, 1976). For example, in using information to solve a specific problem, individuals are more likely to remember what they have learned, more likely to process the information they are receiving, and more likely to reflect on how they learned. Lastly, the active learning environment allows the opportunity to develop multiple learning skills simultaneously, for example critical thinking, analysis of literature, and oral and written skills associated with the communication of problem analysis.

In any course structure with a set of well-considered intended learning outcomes, it is unequivocal that the teacher has a considerable degree of control over student learning through what is taught and how the teaching is facilitated or delivered. Teachers have power to develop good teaching practices, constructively align teaching and learning activities and fortify the student learning environment within their individual domain of teaching units and courses. According to Biggs and Tang (2007) quality learning depends on the capitalisation of good teaching methods, where good teaching can be defined as getting most students to use the level of cognitive processes needed to achieve the intended outcomes that the more academic students use spontaneously.

Education can be framed as more about developing and changing rather than filling student minds. I aim to extend the synthesis of students' biochemical understanding through learning activities that emphasis engagement with complex biological concepts and systems. This educational philosophy guides the design of teaching and learning activities and assessment items so that students are both actively thinking about the learning material and applying scientific principles to address complex but tractable problems.
Acquisition of critical thinking and reasoning skills is a core objective of undergraduate education in science (National Research Council, 1996). Significantly, scientific teaching that involves active learning strategies and engagement of students in discovery and scientific process improves learning and knowledge retention (Handelsman, et al., 2004). As a direct consequence, it is argued that active student-directed learning techniques that embrace the principles of effective learning and teaching should be more widely adopted and that implementing such change will enthuse students, create a scientifically literate society and advance research enterprise (Handelsman, et al., 2004). In addition, science education policy reviews (see National Research Council, 1996) have proposed that teaching activities and student learning should focus on developing abilities that include:

- to think critically, and analyse and solve complex, real-world problems
- to find, evaluate, and use appropriate learning resources
- to work cooperatively in teams and small groups
- to demonstrate effective oral and written communication skills
- to use content knowledge and intellectual skills to become continual (lifelong) learners.

Teaching and learning activities for functioning knowledge focus on developing higher level graduate capabilities that establish professional competencies and skills that can be applied by graduates in real-world working situations. Biggs and Tang (2007) submit that the development of competencies and skills that equip students for professional decision making rely, firstly, on building an appropriate declarative knowledge base, and, secondly, on being able to apply that knowledge through authentic and practical exercises and learning situations. Consequently, the teaching and learning activities that underpin functioning and professional knowledge aim for learning outcomes that reflect an ability to 'apply', 'create', 'synthesise' and 'solve problems.'

Learning models that promote the development of these skills include case-based learning (CBL) (Herreid, 1998, 2004; Hutchings, 1993) and problem-based learning (PBL) (Duch, Allen, & White, 1999; Duch, Groh, & Allen, 2001; Wood, 2004). The case study method is an active, learner-centered model, which has long been used to facilitate the development of reasoning skills and to connect classroom teaching to real world scenarios in such disciplines as psychology, business, law and medicine (Hutchings, 1993). A case, problem or inquiry is used to stimulate the acquisition of knowledge, skills and attitudes, so that these teaching and learning activities are placed in a context that promotes authentic learning. Supporting information is usually provided in the form of research articles, laboratory results and data. CBL, unlike PBL, requires that students possess a degree of prior knowledge that can assist in solving the problem. Case studies can be used to teach content, engage students with real life data or provide opportunities for students to put themselves in a professionally-related decision making position. The process of CBL facilitates the construction of declarative knowledge as well as the development of analytical, team working and communication skills. A further characteristic feature of both CBL and PBL is the requirement of the student to assume greater responsibility for their own learning (Biggs and Tang, 2007). Although these educational models are used most commonly in professional education programs, such as medicine, they have been broadly implemented within many basic scientific disciplines. Despite this, traditional science education concentrates on disseminating and teaching conventional scientific theory and practice, which ineffectively supports the development of creative intellectual thinking, upon which the very foundations of scientific inquiry depends.

CBL and PBL have roots in the constructivist education paradigm known as discovery learning. The foundational theory of discovery learning was formulated and advanced in the 1960s as 'learning by doing' through inquiry-based instruction and learning. Jerome Bruner a central figure in the promulgation of discovery learning theory, contends that discovery learning is "a necessary condition for learning the variety of techniques of problem solving, of transforming information for better use, indeed for learning how to go about the very task of learning" (Bruner, 1961, p. 60).

Importantly, discovery learning relies on a constructivist approach to education, and, as such, adheres to the central principle of constructivism, which advances that knowledge and meaning is generated from individuals' experiences. Discovery learning embraces problem solving situations as the environment in which the student can actively draw on their past experiences and knowledge to discover new facts and effectively develop deep conceptual understanding. Furthermore, Bruner viewed discovery learning as an educational model that enabled the learner to continually connect theory and practice. Taken as a whole, it is proposed that integration of discovery learning as an instruction tool promotes:

- Active engagement
- Motivation
- Autonomy, independence and responsibility
- The development of creativity and problem-solving skills.

It is incontrovertible that acquisition of these capabilities is critical and discriminative for advanced and authentic learning in all disciplines, but especially significant for science. Furthermore, such skills and characteristics will give students an edge in the competitive employment market of the real world.

The introduction of change into what we teach or how we teach poses the central question of how do we determine whether the innovation that we have launched in our classroom and onto our students is effective and worthwhile. To these ends it can be determinative and insightful to apply an action research approach. Critically, action research investigates changed practices through a series of self-reflective spiral cycles, where each cycle consists of a sequence of 'reflect, plan, act, observe' steps (Kember & Kelly, 1993).

The project described in this paper integrated a constructivist teaching strategy into a mandatory advanced (3rd year) level Biochemistry major unit within an Applied Science degree program. The unit, called Functional Biochemistry, is an ostensibly 'new' unit that appeared in a restructured degree program for the first time in Semester 1, 2010. The teaching team responsible for lecture delivery was essentially the same in the old and the new unit. The key difference between this new unit and the unit that it replaced is the introduction of a constructivist teaching and learning strategy, which promotes alignment between the teaching and learning activities (theoretical and conceptual lecture material, practical laboratory experiences, and case studies) and the assessment items within this teaching unit. Specifically, we have added a set of CBL activities into the teaching/learning framework that are designed to consolidate student learning and understanding and develop problem-solving, team work and communication skills. Most importantly, the CBL activities are designed to enable students to develop linkages between the teaching and learning activities within the theoretical and practical components of the unit and with the assessment items. In this way, the teaching and learning activities are constructively aligned and congruent with the assessment framework. A comparison of the teaching and learning activities and assessment structures, and their alignment in the former and the new unit are highlighted in Figure 1.

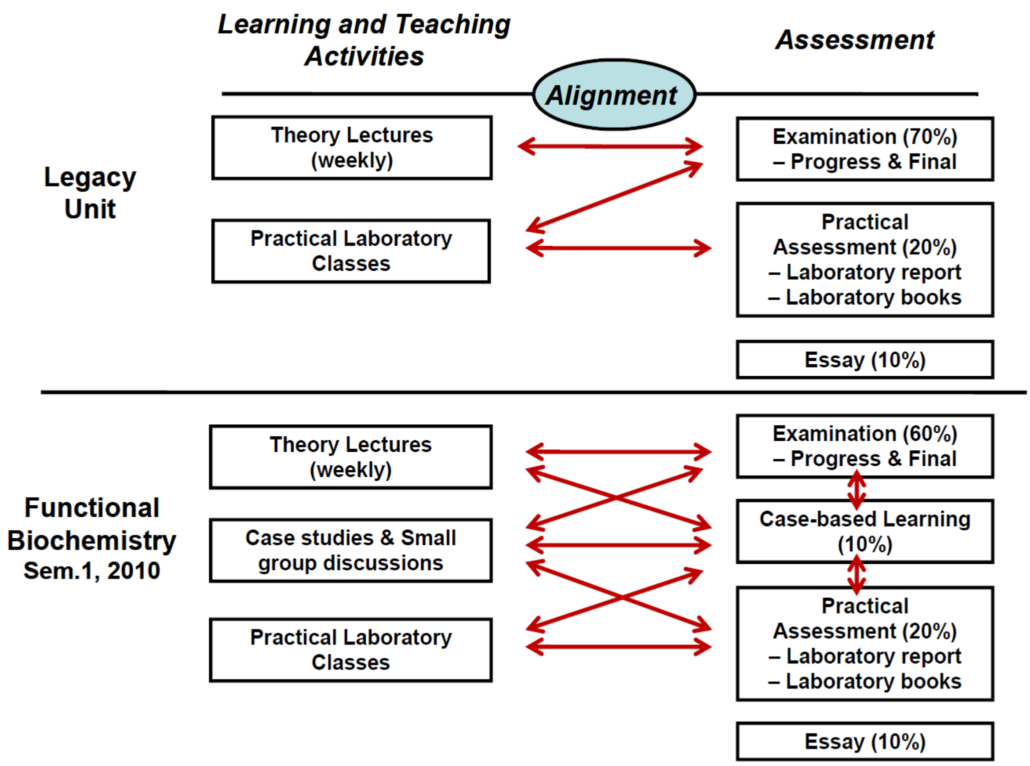

Figure 1: Comparison of alignment between teaching and learning activities and assessment structures in the legacy unit and the new unit commencing in Semester 1, 2010.

The first cycle of the action research plan launched and integrated a constructivist teaching strategy and alignment into the new final year biochemistry major unit through the addition of a set of case studies and small-group discussions (~12 students in each group). Consequently, the basic objective is the introduction of constructive alignment between the teaching and learning activities and the assessment items, and this objective will be realised through the introduction of a set of case studies and CBL into this unit. Specifically, these case studies use primary biochemistry research articles as the source of the problems and integrate (and further develop) the students' learning with the conceptual theory material covered within the framework of the lectures. Furthermore, the case studies reinforce student engagement with theoretical learning material, practical experiences and assessment items. As a consequence of this approach students are be supported in their acquisition of competencies and skills in reading, assimilation and interpretation of primary research articles, as well as team working and communication skills. Importantly, these skills are widely regarded as being advanced-level science skills and graduate attributes that are essentially required for further study (higher degree) in science and research-focused careers (Biochemical Society Curriculum Working Party Report, 2002; National Research Council, 1996).

Methods

In this paper, a constructivist teaching strategy has been introduced into a new unit. The constructivist teaching strategy aimed to integrate the teaching and learning activities to the assessment items, and a set of case studies (CBL) function as the central teaching and learning activity that facilitates alignment. I investigated how students are using active learning strategies and developing team working, communication and problem-solving skills, and determined whether their experiences correlated with their overall level of satisfaction and performance (grades) in this unit. The research questions were investigated using a multipartite strategy.

Survey / One minute papers

One minute papers were completed by the students at the conclusion of the 2nd and 3rd case study sessions. A custom designed survey of the enrolled students was completed in class towards the end of the teaching period. The survey comprised targeted questions (5-point Likert scale) addressing the student perceptions of benefit and utility of the case studies and small-group discussions. Students were also given the opportunity to answer a set of open-ended questions.

Interviews

Individual interviews of students enrolled in this unit were undertaken. In total, five students were interviewed, each interview lasted between 20 – 30 min, and 3 representative interviews were analysed further. The objective of the interviews was to investigate student observations and perceptions of the CBL activities and how these CBL activities integrate and align with the other teaching and learning activities within the unit. In addition, the interviews focused on the perceived learning benefit of teamwork and problem-solving skills. Each interview consisted of 5 broad questions directly related to the processes and skills utilised in working through the case study learning activities and 4 additional questions on general topics related to biochemistry as a study area. Each interview was recorded (MP3 format) and the conversations lasted between 20-30 minutes, and interviews with 3 students were transcribed and subjected to further review and scrutiny.

Analysis of institutional student evaluation survey data

Data from the institutional student evaluation survey (QUT Learning Experience (LEX) survey) for Functional Biochemistry (semester 1, 2010) was compared to the outcomes obtained in the former teaching unit (2008 and 2009).

Analysis of cohort marks and grades

The marks and grades for students enrolled in Functional Biochemistry (semester 1, 2010) were compared to the marks and grades obtained in the former unit in 2008 and 2009. Class sizes in this advanced level biochemistry unit were similar over the 3 year period (2008 – 2010) and each year the cohort of students was largely biochemistry major students with similar backgrounds, capabilities and grade point averages.

Results and Discussion

The student responses to the questions posed by the minute papers were analysed and grouped according to the common themes that were presented. These data are shown in Table 1 and the qualitative summary of the responses indicates that the case-based learning tasks were approached by the students using active learning processes. The first question on the minute papers asked ‘What approaches do you take when trying to solve these types of problems?’ Several themes were common amongst the responses. It was clear that teamwork, group discussions and knowledge sharing were strategies utilised by students. In addition, reading research articles and database searches were expounded as effective approaches to solving CBL problems.

The second minute paper question asked ‘What are the most valuable skills you learnt from the case study?’ Again, a considerable number of the student responses indicated that the case studies were being tackled using advanced active learning skills, including problem solving, critical thinking, data analysis and teamwork.

The final question on the minute papers asked ‘What is not clear or confusing about the case study we worked on today?’ By and large, the responses indicated that the case studies were presented in a clear and understandable manner and that students did not find the process of working through the case study problems confusing. However, minor themes that were represented on 2 separate responses from the student groups were that the case studies used confusing terminology, lacked a degree of direction and instruction, and that time was a factor in the satisfactory and effective completion of the case study for certain students.

Overall, the responses from the minute papers (Figure 2) demonstrate that students are actively engaging with the case studies and employing higher order learning strategies to research, analyse, apply knowledge and solve the problems presented in the case studies. The outcomes are grouped according to the major teaching and learning themes detailed by the responses from the minute papers.

	Minute Paper 1		Minute Paper 2	
	Themes	*Number of affirmations*	*Themes*	*Number of affirmations*
Question 1: *What approaches do you take when trying to solve these types of problems?*	**Reading research articles and database searching**	**8**	**Teamwork / knowledge sharing**	**6**
	Apply knowledge	**2**	**Problem solving**	**2**
	Teamwork and group discussions	**5**	**Apply knowledge**	**4**
Question 2: *What are the most valuable skills you learnt from the case study?*	**Critical thinking / Problem solving**	**7**	**Critical thinking / Problem solving**	**5**
			Data analysis	**3**
	Data analysis	**8**	**Teamwork**	**9**
	Teamwork	**5**	**Communication skills**	**3**
			Apply knowledge	**3**
Question 3: *What is not clear or confusing about the case study we worked on today?*	**Lack of direction and instructions**	**2**	**Time constraints**	**2**
	Confusing terminology	**2**		

Figure 2: Qualitative summary of student responses to the minute paper questions.

The students were also asked to complete a survey that presented a series of 10 statements directly related to the case studies as a teaching and learning activity and the way in which students learn and develop knowledge in biochemistry. The outcomes to the survey are presented in Table 1 as a mean score (out of 5), where a score of 5 indicates strong agreement, a score of 3 is neutral and a score of 1 indicates strong disagreement. Overall, there was agreement with 8 of the statements, minor disagreement with one statement and neutrality on one statement. The highest level of agreement (mean score = 4.1) was expressed for the statement *'I believe that I will be able to use and apply these problem solving skills in a team-based workplace environment'*. The student cohort also agreed (mean score = 4.0) that *'Biochemistry is most effectively assessed through practical-based and problem solving assessment'*. The survey further questioned student attitudes about their preferred teaching and learning style with the outcome suggesting that students may prefer to learn biochemistry through doing and discussion over and above lecture-style teaching.

Table 1. *Student responses to the case study survey were determined from a 5-point Likert scale and presented as mean scores (n = 17)*

Statement	Mean Question Score (scale of 5 max.)
I believe that the case-based studies have helped me to understand biochemical problems and their solutions better.	3.6
The case-based studies have increased my confidence and ability to read and understand scientific articles.	3.7
The case-based studies have stimulated my interest in research.	3.6
I prefer learning biochemistry through lecture-style teaching	2.6
I prefer learning biochemistry through doing and discussion	3.8
This unit has helped me develop problem solving skills that can be used to investigate real world problems.	3.8
I believe that I will be able to use and apply these problem solving skills in a team-based workplace environment	4.1
Biochemistry is most effectively assessed through examinations	3.2
Biochemistry is most effectively assessed through practical-based and problem solving assessment	4.0
The case-based studies were well integrated and aligned with the lecture content, the practicals and the assessment in this unit.	3.7

Note to Table 1: A score of 5 equals strong agreement and a score of 1 equals strong disagreement.

Students enrolled in Functional Biochemistry were invited to be interviewed. Overall, five interviews were conducted and 3 representative interviews were transcribed and analysed qualitatively. The outcomes of the interviews are presented (Table 2) as a summary of key words, descriptive phrases and comments given by the individual students in the transcripts of their answers to the specific questions. The qualitative data presented in Table 2 compellingly demonstrate that all 3 students feel that the CBL activities helped them develop their skills in data analysis and data interpretation, problem solving and working collaboratively in small groups. In addition, two of the three student interviews stated that the CBL activities enabled them to strengthen their biochemistry knowledge base and apply that knowledge. Overall, all three interviewees used a strikingly common language when answering the questions, suggesting that the student cohort in this unit strongly agrees that the CBL activities are definitely valuable and constructively develop advanced level scientific skills. Furthermore, there was concordance between the interviewees that the CBL activities and small group discussions were aligned with the theory lecture material, the practical classes and related assessment items.

In the final part of the project reported herein, I examined data from the institutional student evaluation surveys and student performances (grades) in this unit compared with the former unit that ran in 2008 and 2009. To determine the levels of student satisfaction in Functional Biochemistry (semester 1, 2010), I accessed the institutional (QUT) data available from the Learning Experience (LEX) Survey and compared this data to reports from the former unit in 2008 and 2009 (Table 3). It is emphatically clear that the LEX unit ratings for Functional Biochemistry are considerably higher than the unit ratings for the former unit (both 2009 and 2008) across the 5 unit item descriptors (UO1 – UO5) used in the evaluation survey (see Table 3 for the unit item descriptor questions). The improvements in scores evidenced for Functional Biochemistry are

Table 2: *Analysis of student interviews. Outcomes of the interview questions are presented as a summary of key words and phrases used by the student to answer the questions.*

Interview Questions	Summary of responses presented as sets of key words, descriptive phrases and brief comments		
	Interview #1	**Interview #2**	**Interview #3**
How did your learning benefit from solving the problems and discussing them in the small group situation? What specific skills do you think you developed or acquired?	Team work; collaborative discussion; integrate and connect different perspectives; motivation to actively think and apply knowledge	Team work; critical reflection on solution to problems; effective communication skills; developing different skills	Team work; emphasise different modes of problem solving; data analysis and interpretation
What steps did you take to solve the problems and develop your learning? Why did you do these things?	Work individually then bring answers for discussion with group; use reputable databases and information sources	Self-directed learning; work individually then bring answers for discussion with group	Work individually, bring answers for discussion with group; read, brainstorm and extend ideas in class; use authentic reference sources
Is there anything confusing or unclear about problem-solving and problem-solving skills?	Initial lack of clear instruction and learning objectives	Nothing specific	Nothing specific
How did the topics in the case studies integrate or align with the theory, practical and assessment in the unit?	The first case study aligned with the enzymes lecture, enzyme practical, the practical report and the progress exam	The first case study aligned the enzymes lecture, enzyme practical, and the practical report	All case studies aligned with practical and assessment
How has the unit developed your skills and the way you think about biochemistry?	Enabled expansion and building of my biochemistry knowledge base	Practical skills; good time management; advancing knowledge base; self-directed learning	Problem-solving skills; research skills
Can you describe something (theory or practical) in the unit that you have found meaningful and can be applied beyond biochemistry?	Teamwork; collaboration with fellow students; bringing different views and answers to a group discussion	Communication skills; research skills	Data analysis; data interpretation
How do you think these problem-solving skills can be applied outside of your degree?	Teamwork; collaborative discussion; data analysis skills	Teamwork; research skills; communication skills; need more opportunities to develop these skills in the course	Data analysis and data interpretation skills that will be applicable to research laboratory work

between 0.5 and 1.0 point (on a scale of 5) across the set of unit item descriptors (UO1 – UO5). It is proposed that the students enrolled in Functional Biochemistry (Semester 1, 2010) have been more satisfied with the learning and teaching activities in the unit and feel that the unit has provided worthwhile and valuable learning experiences.

Table 3: *Comparative data showing the unit outcomes in the QUT Learning Experience Survey (LEX) for Functional Biochemistry (semester 1, 2010) and the legacy unit (2008 and 2009).*

Year	**Unit Name**	**Response Rate**	**Unit Item Descriptions (Score / 5)**				
			UO1	**UO2**	**UO3**	**UO4**	**UO5**
2008	Former Unit	40 %	3.6	3.4	3.1	3.4	3.6
2009	Former Unit	36 %	3.8	3.4	3.3	3.3	3.3
2010	Functional Biochemistry	50 %	4.3	4.2	4.2	4.3	4.3

Notes to Table 3: Unit Item Descriptions
U01 - The unit activities helped me develop useful skills and knowledge.
U02 - The relevance of the unit activities was clear.
U03 - The structure and organisation of the unit assisted my learning.
U04 - I received helpful feedback on my learning.
U05 - I have been satisfied with the overall quality of this unit.

Student performance (grades) in Functional Biochemistry is shown in Table 4 and can be compared to the student performance in the former unit in 2008 and 2009. The total number of enrolled students in the current unit was 22, and 21 out of 22 students passed (achieved > 50%) the unit. Significantly, this pass rate is a distinct improvement when compared to the legacy unit, which showed failure rates of 18.2% and 21.7% of the enrolled students in 2008 and 2009, respectively. It is particularly striking to observe that more that 60% of the enrolled students in Functional Biochemistry achieved a grade of either 6 or 7 (on a grading scale where 6 is a distinction (75% - 84%) and 7 is a high distinction (85 – 100%)). This contrasts to only 27.3% and 21.7% of the enrolled students achieving grades of 6 and 7 in 2008 and 2009, respectively. However, it is worthwhile to note that the award of 7 grades (9.1%) in Functional Biochemistry is consistent with the award of 7 grades in the former unit in previous years. Overall, it is evident that the curriculum review, increased focus on constructive alignment, and the introduction of CBL activities in Functional Biochemistry have markedly changed (for the better) the grade profile of the unit when compared to the legacy unit from which Functional Biochemistry was spawned.

Table 4: *Comparative data showing the academic performance (grades) of students in Functional Biochemistry (Semester 1, 2010) and academic performance in the legacy unit (Semester 1, 2008 and 2009).*

Year	Unit name	Grade	7	6	5	4	3	2	1	Failure rate
2008	Former Unit (*n*=33)	#	2	7	10	8	1	5	-	18.2%
		%	6.1	21.2	30.3	24.2	3.0	15.2	-	
2009	Former Unit (*n*=23)	#	2	3	9	4	-	1	4	21.7%
		%	8.7	13.0	39.1	17.4	-	4.3	17.4	
2010	Functional Biochemistry (*n*=22)	#	2	12	2	5	-	-	1	4.5%
		%	9.1	54.5	9.1	22.7	-	-	4.5	

In conclusion, the findings of this paper support the view that constructive alignment between the teaching and learning activities and the assessment in Functional Biochemistry has been immensely valuable for the learners enrolled in this advanced level biochemistry unit. A central element of constructivist epistemology advances the implementation of teaching and learning strategies that facilitate the construction of knowledge. Consequently, strategies that develop, encourage and facilitate the construction of knowledge promote the creation of a learning environment where students are motivated to actively think and apply their knowledge gained from the subject. Specifically, in this study CBL activities underpin the constructive alignment and it is proposed that the introduction of CBL activities into the teaching and learning activity framework of Functional Biochemistry facilitate the development of problem-solving skills, consolidate student learning and understanding, and establish linkages and alignment between the theoretical learning material (lectures), practical experiences and assessment items in a constructivist structure. Moreover, the evidence presented in this report establishes that the introduction of a set of CBL activities can work to positively influence the constructive alignment of the teaching and learning activities and the assessment items, and, overall, that this approach supports and boosts student satisfaction and leads to improved student performance.

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