The Need and Value of Biosciences in Dental Education: Embedding Biosciences into Curricula to Foster Deep Learning and Improve Learning Outcomes and Experiences

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Abstract

It is generally taken for granted that dental education must include basic biosciences in the curricula. However, debate still exists about its usefulness and the best methods to teach it in dental schools. The objective of this paper is to review and explore the arguments surrounding the need for bioscience in a dental curriculum and develop a rationale of curriculum design principles for bioscience dentistry subjects. In this context, an example of the redesign of a dental human bioscience subject at La Trobe University was used. The basic biosciences teach how scientific reasoning can be applied to clinical decision making and provides a framework for solving clinical problems. Competency in applying bioscience principles to clinical problems is best achieved when it is integrated in a clinical context using active learning methods, like a hybrid problem based-learning program. Also, by adopting active learning environments this will encourage a broader range of skills and capabilities like teamwork and communication, attributes that oral health professionals will need in the future. Dental students will be better prepared to learn, understand and apply bioscience concepts if these important curriculum design principles are followed.

Background: The value for bioscience in dental education

The Flexner report, a review of medical education in the USA and Canada, published in 1910, recommended that medical education begin with a strong foundation in the basic medical sciences followed by the study of clinical thinking (Flexner, 1910). The dental counterpart the 'Gies report' followed (Geis, 1926). Although there have been modifications such as evolving more integrated and self-directed approaches to learning, these reports have no doubt influenced and set the model for the pattern of medical and dental education for the last 100 years (Weatherall, 2006). The formative role of bioscience learning has been integral to these models. Bioscience knowledge was felt to be critical for clinical application and serve to inform effective thinking skills.

Despite it being widely incorporated, the role of bioscience teaching and learning in clinical programs is robustly debated (Weatherall, 2006; Finnerty, Chauvin, Bonaminio, Andrews, Carroll & Pangaro, 2010). Stimulating the debate in Australia was the Australian Medical Education Study (AMES) in 2008 that expressed concern that the depth of bioscience knowledge needed for acquiring expertise was not adequately defined in most medical programs, and that did not align well with stakeholders' expectations at the professional level of training (McColl, Bilszta & Harrap, 2012). This caused debate that general bioscience education may waste valuable space in the curriculum and was largely irrelevant. Its suggested removal is often related with the concept that medical and dental curricula are already too long and hence costly (Weatherall, 2011).

In contrast, there are various arguments by which bioscience learning is beneficial to dental programs. One of the major arguments is that it assists in acquiring clinical knowledge and skills by helping students understand the underlying theoretical concepts that can be applied to clinical practice. In this way, basic biosciences can have many important applications to dentistry. An obvious example of this is pharmacology which can assist in making a calculated choice of local anaesthetics and their effect on individuals for exactions, the choice of analgesics, and also when considering contraindications and allergies. A third example is anatomy that would support in learning where to inject for local anaesthesia and understanding the ensuing pattern of effects due to the distribution of nerves; understanding normal and abnormal joint action associated with temporomandibular joint dysfunction, understanding saliva production and fascial planes with spread of infection. Another example is pathophysiology knowledge which would assist in understanding inflammation, the healing following gingivitis (causing recession), the time interval to follow for bony healing after extraction for implant placements or denture amendments and to understand why not to rinse after extractions to keep clots within the bony socket to maximize bony healing after extraction. Dentistry (like medicine) is based upon recognizing the abnormal. But to first appreciate what is abnormal, a dentist must have a firm foundation in what is normal. Many bioscience disciplines in various ways can define these parameters.

There are many studies that support the suggestion that bioscience knowledge is helpful in clinical situations. For example, amongst medical students those with a deep fundamental understanding of basic science were better able to address uncommon and more complex clinical situations than those relying solely on presentation and algorithm (Woods, Neville, Levinson, Howey, Oczkowski & Norman, 2006). Also, Baghdady, Pharoah, Regehr, Lam & Woods (2009) showed that dentistry students who were taught to identify pathophysiological features using basic bioscience performed better on immediate recall tests than students taught using a structured list of clinical features. Studying biosciences also enables students to develop an interest in various career paths, such as becoming academics, researchers or specialist consultants. This could translate into advancements in areas such as biomaterials in clinical settings, and so help grow the discipline and profession (Iacopino, 2007). Traditionally, dental students do not have an appreciation for the application/importance of research and discovery of new knowledge and skills to patient care activities (Bertolami, 2002). An increased integration of bioscience with clinical sciences has been hypothesized to help overcome this problem (Iacopino, 2007).

It is also proposed that understanding and applying biosciences help develop skills for evidence based practice (Sweeney, 1999; Grande, 2009). For example, knowledge in anatomy and physiology could allow dentists to appraise the relevance of evidence to a specific clinical case, and develop an organised and critical approach, so that appropriate comparisons and choices can be made and justified. Though there is no direct evidence to support this link, it does appear instinctive that a grounding of bioscience knowledge is required to develop and apply evidence-based practice skills and to formulate clinical questions.

Introduction

During the early 1940s the aim of a dentistry course, as now, was to produce competent practitioners who could immediately and safely go into independent dental practice. In most schools, however, special courses in the biosciences were not provided for dental students, rather there was a heavy bias toward repeated practice of both simple and complicated restorative and prosthetic procedures (Moore, 1984). Today, although these fundamentals are still very important, the accepted responsibility for dentists to promote the principles of total health care has meant that basic biosciences have gained importance and become a major part of dental education. Traditional basic biosciences include anatomy, physiology, biochemistry, microbiology/immunology, pathology and pharmacology. With the expansion of medical sciences, disciples such as genetics, molecular biology and epidemiology also gained importance. Today's dentists are expected to understand the nature of the oral condition in the context of general disease. This concept of whole-mouth and whole-patient care has lead the Dental Board of Australia (and UK equivalent) to formally outline that students require definitive biomedical science knowledge upon graduation.

Although it is generally taken for granted that dental education now include biosciences, questions still remain about its usefulness and the best methods to teach it to dental students. This paper intends to explore the questions: how does bioscience knowledge in dental education help students become more professional, competent dentists? And if so what are the most effective teaching and learning methods to facilitate student learning outcomes and experiences? In exploring these questions, this paper will discuss and develop a rationale for curriculum design principles for bioscience dentistry subjects aimed to more effectively embed the relevance of bioscience in a dental curriculum. The paper will also provide an example of applying these principles for the redesign of a dental bioscience subject (Dental Science A) at La Trobe University. This is a core subject in first semester of first year as a part of the Bachelor of Health Science in Dentistry/Master of Dentistry course (that covers physiology, biochemistry and anatomy). It is an undergraduate level entry dentistry course, unlike some other universities in Australia that are only post graduate-entry level courses. Undergraduate level entry students build upon the science knowledge they gained from school, and require prerequisites of Victorian Certificate of Education Units 3 & 4 in Biology and Chemistry. Given the competition for places and high grades necessary to gain entry into dentistry, dental students are generally academic high achievers. Nonetheless, the quality of students learning is related to the quality of students approach to learning (Biggs, 1989; Trigwell & Prosser, 1991). The aim is to therefore to develop curriculum design principles for this particular cohort of students to foster a deep approach to learning in bioscience and improve learning outcomes and experiences, to better relate and compliment bioscience with clinical disciplines and ultimately produce more competent dentists in the future.

Bioscience for dentistry: key teaching and learning approaches to consider

The integration of biosciences theoretical and clinical learning

For most dentistry subjects at La Trobe University, basic biosciences are taught predominantly prior to or separate to the teaching of clinically related topics. This approach reflects the traditional Flexner model that promotes a separation between bioscience learning and clinical learning (Flexner, 1910). This approach follows the 'two worlds' model whereby theory and practice are not integrated and bioscience knowledge is largely kept separate from clinical knowledge to create two worlds that only minimally interact during reasoning (Patel, Evans & Groen, 1989). The rationale here is that dentists seldom use basic science when describing patient presentations, instead they depend on clinical knowledge, associations and classifications to formulate solutions to diagnostic problems (Patel *et al.*, 1989). This approach recognises the importance of bioscience as providing a foundation to understand the theoretical basis of clinical practice.

In contrast, emerging evidence suggests that this approach may not be the most effective way of developing clinical expertise; rather, a more integrated approach is being promoted. Consequently, for the last several years curricula are being designed to bring clinical education forward into the earlier years, thus giving the opportunity to teach the relevant biomedical sciences alongside the corresponding clinical components. This integration approach has been found to promote better understandings amongst medical students (Dahle, Brynhildsen, Behrbohm Fallsberg, Rundquist & Hammar, 2002). Also, vertical integration of oral physiology and clinical dentistry has been shown to help dental students score significantly higher on questionnaires testing dental pain compared to students who were only taught oro-facial pain as a standalone (Ali, O'Sullivan, Gray, Vowles & Hooper, 2009). This suggested that a closer integration of bioscience with clinical teaching helps students understand the physiology of a process and apply this knowledge so that they can understand better the pathophysiology of the disease process. Studies like these suggest an integration approach to bioscience knowledge not only provides scaffolding for clinicians to understand the biological mechanisms of advanced practice, but also can work in partnership with clinical learning to advance and improve skills. In addition, a lack of integration between bioscience and clinical-related topics has been shown to lead to students to undervalue their basic scientific training (Chapman, 1979).

Problem-based learning

Having made a case for embedding biosciences into the curricula, I will now explore the best ways to teach the syllabus to enhance student learning experiences and outcomes.

Over the past 15 years or so, all dental schools in Australia have introduced problem based learning (PBL) approaches to their programs, with the nature of the PBL components introduced varying from school to school. Fundamentally the PBL approach involves academics acting as facilitators of learning, where they interact more closely with smaller groups of students. By their design, the problems encourage a multidisciplinary approach and the need to apply knowledge in a particular situation. It represents a change in focus from teachers and teaching in conventional lecture based programs to learners and learning (Winning & Townsend, 2007). It is proposed that students learn best by building their own knowledge within clinical contexts and so is more effectively developing student's diagnostic reasoning skills (Schmidt, Machiels-Bongaerts, Hermans, ten Cate, Venekamp & Boshuizen, 1996; Kaufman & Mann, 1998).

When PBL sessions are organized around clinical problems, it is a motivating and exciting way to learn because students are better able to perceive the clinical relevance of basic sciences. Therefore, generally students enjoy PBL more than conventional programs (Vernon & Blake, 1993; Bernstein, Tipping, Bercovitz & Skinner, 1995). Studies showed that PBL students were more likely to study for understanding, rather than for the short-term recall and were more likely to use library recourses to study (Albanese & Mitchell, 1993). An environment that fosters students to become more responsible for their own learning is the result (Winning & Townsend, 2007). It was proposed PBL provides explicit opportunities to improve clinical decision making, research competence and interdisciplinary thinking (Hmelo & Lin, 2000; Keeve, Gerhards, Arnold, Zimmer & Zollner, 2012). All competencies which are highly sort after in the dental profession.

Great opportunities to improve teamwork skills are possible through PBL activities. Active learning fosters skills in communication and cooperation, negotiation, listening and will encourage self-reflection and the ability to deal with criticism and feedback (Kersten, Vervoorn, Zijlstra, Blok & van Eijden, 2007; McKinley & Stoll, 1994; Jaques, 2003). For dental students, developing such skills to promote professional attitudes and behaviours would facilitate effective interactions with patients and colleagues in the future (McDonald & Godfrey, 1999).

Balanced against the apparent benefits of PBL, are some reports that the amount of bioscience knowledge students gain from PBL programs is less than that of students from conventional courses (Vernon & Blake, 1993). Similarly, even supporters of PBL conclude that it does not seem to lead to marked improvements in cognitive outcomes (Albanese & Mitchell, 1993; Norman & Schmidt, 2000). Other disadvantages include the need for skilled facilitators and the potential increased costs of implementation and maintenance of this small group format (Winning & Townsend, 2007). In contrast, growing evidence indicates a well planned hybrid PBL program, with matched methods of assessment, could be a good compromise. Hybrid versions of dental education consist of a combination of both PBL packages and more conventional lectures, tutorial, online modules and recourses and clinical practice. Dental students enrolled in a hybrid PBL curriculum demonstrated a greater ability to apply basic science principles to a clinical scenario when compared to students in a traditional lecture-based curriculum (Callis, McCann, Schneiderman, Babler, Lacy & Hale, 2010). Other research showed that students that participated in a true PBL curriculum have a desire for some traditional lectures (Haghparast, Sedghizadeh, Shuler, Ferati & Christersson, 2007). Therefore, a hybrid program could incorporate the benefits of a PBL format yet provide the structure that most PBL students find lacking, while also making it more viable to implement financially.

Redesigning dental science subject

The purpose of the Dental Science A subject at La Trobe University is to provide students with the opportunity to acquire a fundamental understanding of human life processes, and to introduce the students to the basic structure and function of human organ systems, and biological chemistry. It also aims to lay the foundations of understanding how and why humans have the dentition they have, and how developmental defects affect the face and teeth. There are both human biosciences and dental component to the subject. The human bioscience component covers physiology, biochemistry and anatomy. The dental component introduces clinical teaching, covering dental anatomy, histology and embryology to complement and extend the teaching carried out in other subjects. Students explore these topics in lectures, practical classes and tutorial sessions.

The redesign of this subject is primarily motivated by the need to update and better reflect the 'Design for Learning: Curriculum Review and Renewal at La Trobe University' report, that was accepted by the Academic Board in 2009. The initiative aims to

> …improve the quality of undergraduate student engagement, learning, and academic success by addressing, amongst other things, the first year experience, curriculum design, course mapping, and the evaluation of learning outcomes and standards. (http://www.latrobe.edu.au/ctlc/dfl/index.html)

In addition to the University's initiative report, motivation and stimulus for redesigning the subject has also come from both dental academics and students. Dental academics are now beginning to embrace the need for the curriculum to focus less on traditional didactic learning methods and more on deeper-learning approaches. Students have expressed their difficultly in grasping the relevance of bioscience in their dental profession for the future. It is difficult for students to appreciate the details of bioscience if it is not clearly correlated with clinical problems. Better integration of bioscience with clinical disciplines would address this and improve motivation. Also, upon reflection from academics and feedback from students it's apparent students are finding 2nd and 3rd year a huge leap in difficulty from 1st year. This could highlight the need to improve learning outcomes in the 1st year Dental Science A subject. A method for achieving this could be through more varied activities, including those considered more engaging for students, like group tasks. Efforts to introduce group work in practical classes in 2012 (with students working in pairs) was greeted with a small improvement in student feedback on the subject, with students on average believing the subject improved their critical thinking skills greater (3.4/5 in 2011 compared to 3.7/5 in 2012). However, a more concerted and wide-ranging effort to redesign and address the issues of the subject could improve bioscience learning, and thus student feedback even more.

Based on the 'Design for Learning' principles, feedback from both dental academics and students, and the teaching and learning approaches important to bioscience for dentistry (that were considered earlier); the following key redesign issues to address are proposed:

- Introduction of group active learning activities (hybrid PBL programme)
- Increase the integration between human biosciences and dental components
- Review the weighting and inclusion of certain bioscience topics
- Introduce collaborative testing

The Dental Science A subject in 2012 had a cohort of 48 students and 5 staff members were involved in teaching the subject. The 2012 curriculum included three 1 hour lectures and one 1 hour tutorial per week. The tutorial served as question and answer sessions for the lecture material. There were also four 2 hour practical sessions per semester, which involved students answering questions from practical notes for individual assessment (Fig. 1). It was proposed for the redesign that the tutorials and practicals be replaced by 2 hour PBL sessions each week, where students work in small groups (4-5) on bioscience/physiology problems (Fig. 1). Group scenario-based learning activities shift the focus of learning away from a didactic approach to an active inquiry based approach (Brown, 2010). The students would be encouraged to discuss the problems and formulate solutions together in their groups. One facilitator per class provided assistance with problems when asked. Each PBL session had a maximum of 24-26 students to enable efficient facilitator interaction. The three lectures per week remained, with each lecture topic scheduled the week before its accompanying PBL session (eg. the cardiovascular system lectures will be followed by the PBL session on the cardiovascular system the next week). This would allow enough time for students to do enough independent learning to be prepared for the PBL activities. The attitude from bioscience staff of the proposed shift toward a hybrid PBL program was very positive and fit within present workloads**.**

The PBL packages were chosen to drive the curriculum and coordinate with topics across the other major streams. In a directed case study design, questions about bioscience were asked that relate to clinical scenarios. The scenario cases were written in collaboration with dental staff that has expert clinical knowledge and experience. Theoretical knowledge of physiology was integrated within the dental framework so that its application to dental clinical skills was made clear. This integration was introduced within lectures and PBL sessions. For example, during the physiology topic of the cardiovascular system when discussing sinus rhythm its application to CPR, ventricular tachycardia and fibrillation was presented as possible clinical scenarios a dentist may encounter. Similarly, for the cardiovascular PBL session, mechanisms controlling blood pressure were presented as clinically relevant scenarios about a patient fainting at the dentist because of the fear and anxiety of the impeding dental procedure. In addition, the choices of local anaesthetic with heart conditions was also discussed. By providing an introduction of bioscience within a clinical context, it would enable students to connect deeper with the bioscience subject matter and understand the relationship between theory, procedure and application (Ramsden, 2003). Students would gain an immediate appreciation for bioscience learning because of its clearer relevance to the dental profession. This approach of closer integration would be more ideal in first year, rather than delaying it for later years, as the bioscience knowledge would be 'fresh' in students minds.

The suitability of bioscience topics taught in Dental Science A should be considered carefully to address an overcrowded and information overloaded first year dental curriculum (Neame, 1984). Studies have suggested oral physiology, blood and the cardiovascular system were considered the most relevant areas in physiology for dentistry (Jiffry, Husain & Dias, 1986; Ramsden, 2003). Systems such as the nervous and endocrine systems could also make a case for being essential for dental students to understand comprehensively for clinical practice. At the moment, however, topics such as the urinary system feature as prominently as the cardiovascular system in the subject. Though the urinary system is very important to gain an overview of human physiology, its relevancy to dentistry compared to some other topics can be argued against. Therefore, bioscience topics which are considered the least essential by the dental staff should be given a diminished role, while other topics expanded. The principle of this redesign is to not only make the subject more professionally relevant, but also encourage depth of learning, even at the expense of breadth of learning (Feather & Fry, 2009).

As learning activities that encourage group work are being introduced, it is necessary to align the assessment tasks accordingly. Therefore it was proposed that collaborative testing be introduced. This involved a multiple choice test that students completed together in their 4-5 member PBL groups. All individuals within the group received the same group mark for this assessment. Studies have suggested that collaborative testing improves student knowledge, critical thinking, promotes interactive team work and problem solving (Tanner, Chatman & Allen, 2003; Michael, 2006). Collaborative testing has also been shown to increase confidence and decrease self-reported anxiety (Kapitanoff, 2009). It was proposed that formal assessment in the subject would take on the distribution for the final grade as; 65% examination, 10% essay assignment and 25% collaborative testing. Collaborative learning works best when individual success is dependent on group success (Tanner *et al.*, 2003). Therefore, it is necessary that in all cooperative learning environments some individual accountability for learning is maintained (Tanner *et al.*, 2003). Thus, it was proposed that collaborative testing be divided into 2 parts, an individual test worth 15% of the final grade that students compete first, followed by the collaborative part worth 10% of the final grade. The collaborative part was open book to encourage research and discussion within the group. There were 2 tests during semester (Figure 1).

Dental Science A syllabus 2012

Week	Class	Assessment
1	3 lectures 1 tute	
2	3 lectures 1 tute	
3	3 lectures 1 tute	
4	3 lectures 1 tute 1 practical	Prac report (3.75%)
5	3 lectures 1 tute	
6	3 lectures 1 tute	
7	3 lectures 1 tute 1 practical	Prac report (3.75%)
8	3 lectures 1 tute 1 practical	Prac report (3.75%)
9	3 lectures 1 tute	
10	3 lectures 1 tute 1 practical	Prac report (3.75%)
11	3 lectures 1 tute	Essay (10%)
12	3 lectures 1 tute	
Exam Period		Final Exam (75%)

Dental Science A syllabus Re-design

Week	Class	Assessment
1	3 lectures	
2	3 lectures 1 PBL session	
3	3 lectures 1 PBL session	
4	3 lectures 1 PBL session	
5	3 lectures 1 PBL session	
6	3 lectures 1 PBL session	
7	3 lectures 1 PBL session	Collaborative test (12.5%)
8	3 lectures 1 PBL session	
9	3 lectures 1 PBL session	Essay (10%)
10	3 lectures 1 PBL session	
11	3 lectures 1 PBL session	
12	3 lectures 1 PBL session	Collaborative test (12.5%)
Exam Period		Final Exam (65%)

Figure 1: Comparison between the Dental Science A syllabus in 2012 compared to the proposed subject re-design.

Preliminary Feedback

In 2013 intermediary steps to integrate human biosciences and dental components of the course were made. Also the hybrid PBL approach was preliminarily implanted into the subject curriculum, with PBL sessions introduced every second week of the semester; however, the assessments remained the same as 2012. This preliminary redesign acted as a preparatory trial to determine the practicability of the implementation of the wider redesign as proposed in this paper. It also provided an opportunity to gain some preliminarily feedback from students. A voluntary anonymous online survey was conducted on the 2013 cohort with approval from the Faculty Human Ethics Committee, of La Trobe University. The survey included 11 Likert scale 1-5 (1= Strongly disagree, 5 = strongly agree) questions asking students perceptions about the subject learning in lectures and PBL sessions. The cohort number in 2013 was 52. There were 19 responses.

Findings from four key questions are shown in Figure 2. Students thought the lectures were very important, 95% of students agreed they were a necessary part of their learning experience (Figure 2a). Similarly, overall the majority of students reported that PBL sessions contributed substantially to their learning (58% agreed) and that PBL sessions also developed

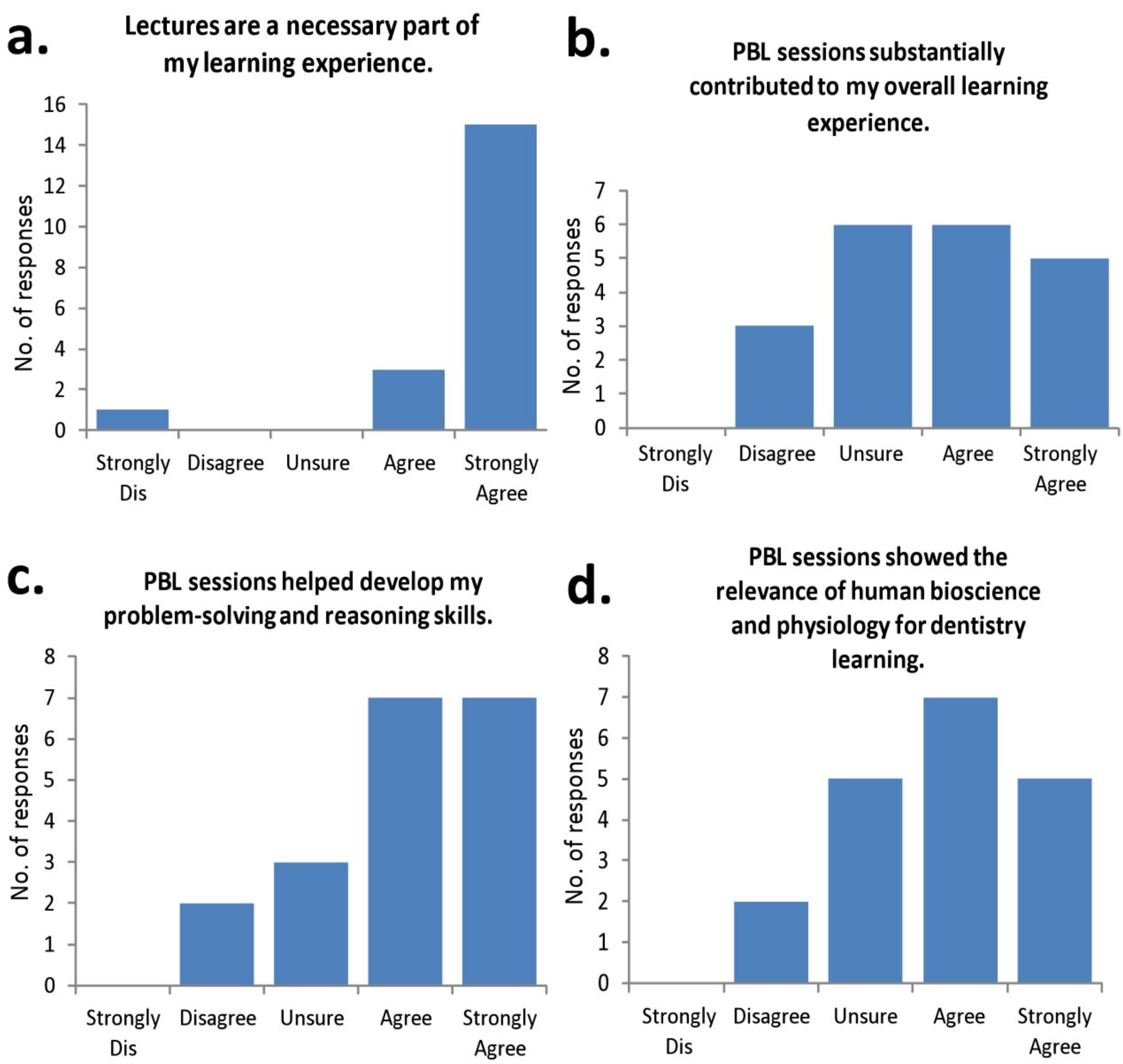

Figure 2: Student feedback from four survey questions that asked about learning experiences from the lectures and PBL sessions used in the 2013 Dental Science A syllabus.

their problem-solving and reasoning skills (74% agreed) (Figure 2b & 2c). These findings suggest students liked the hybrid PBL programme, but any inclusion of PBL sessions should not be at the cost of traditional structured lectures. In addition, most students agreed that the integration within the PBL sessions showed the relevance of human bioscience and physiology for dentistry learning (63% agreed) (Figure 2d). This suggests students had a better understanding of the relevance and importance of bioscience in the greater scheme of their future profession. This recognition and connection being made by students has a positive effect on their bioscience and clinical learning. Further surveys and comparisons between student grades from previous years still need to be conducted to gain a clearer picture of the effects on learning outcomes. The findings here only offer a preliminary insight and more feedback research will be conducted in the future after the implementation of the wider redesign in 2014. But this initial feedback appears positive.

Conclusion

The evidence, although not definitive, supports a significant and important role of bioscience learning in the development of clinical competence amongst dentists. Growing research also advocates the need for an increased integration between bioscience learning and clinical stages of learning, to enhance retention and help the transition to professional practice. This type of approach supports case-based learning and PBL methods.

In this context and against the framework of the 'Design for Learning' policy adopted by La Trobe University (most of the principles of which are derived from Chickering and Gamson (1987)), this paper reflects on key redesign issues that a first year bioscience subject for dental students should consider. This subject redesign consciously attempts to incorporate many of these principles into teaching and learning activities that will ultimately lead to a deeper engagement with bioscience. By adopting and fostering active learning environments it encourages the building of a broader range of skills and capabilities like teamwork and communication. The redesign also promotes a balance by holding high expectations of individual accountability through the use of collaborative tests as a significant role for assessment. Student feedback from preliminary curriculum changes in 2013 showed an overall positive effect on learning. This further strengthens the case for the wider subject redesign proposed.

With the approach proposed here, the two major goals of a basic bioscience curriculum, of providing students the scientific basis for the clinical treatment of patients and developing students' abilities to think and analyse data critically are facilitated and encouraged.

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