The anatomy of engineering education: parallels in teaching the practical aspects of Anatomy and Engineering

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***Abstract**: Traditional University disciplines, such as Anatomy and Engineering, have over the course of their history experienced a long and varied development. For example, in the Engineering discipline computer simulations, videos and virtual laboratories are increasingly replacing laboratory experiments as student numbers increase. Similarly, within the Anatomy, in more recent times with the increasing numbers of students, the use of cadaveric dissection laboratory classes to teach Anatomy has been enhanced or replaced with online learning and 3D models. The advent of modern multi-disciplinary University degrees in Engineering, including Orthopaedic, Biomedical and Sports Engineering, require effective pedagogy paradigms of both Anatomy and Engineering. This paper explores the parallels that exist in the current teaching trends within these two disciplines with the aim of evaluating whether common codes of effective practice exist and can be implemented. A review of both Anatomy and Engineering learning methods was undertaken and the parallels in good teaching practice summarized and compared. The findings show that effective teaching strategies consist of the use of modern technology and the retention of traditional methods in both disciplines. The knowledge gained will benefit the interrelated development by showing how common techniques can and do work. Furthermore, the findings may be applicable to education methods in other science based disciplines.*

Introduction

The introduction of a new Sports Engineering Degree within the School of Mechanical Engineering at the University of Adelaide combines two paradigms of education, Anatomy and Engineering, which require comparative evaluation of pedagogical methods. The advancement of education in the medical sciences (Human Anatomy in particular) has developed significantly in recent years as a direct result of technological progress (Hallgren et al 2002, Biasutto et al 2006, Corton et al 2006). Medical education has always been highly regarded as extremely innovative in its teaching paradigm and it provides a model that engineering education often tries to emulate. Problem Based Learning (PBL) is one such example. Recent evidence (Terrell 2006), however, suggests that some of these evolutionary changes may not be in the best interests of educational quality, and that there is an emerging tendency to return to more traditional practices. However, Mills et al. (2003) suggests that current demands to higher education are unlikely to be satisfied by a traditional engineering curriculum and "chalk and talk" pedagogy and a mixed-mode approach which consists of some traditionally taught courses, particularly in the early years and some project-based components in later years of the program, is required. One issue facing educators is that increasing student numbers have created logistical problems in practical laboratory cadaveric dissection (i.e., the availability of body parts). Modern 3D parametric computer-aided-design (CAD) systems can now effectively synthesise human physiology and anatomy in a digital realm and create geometrically and functionally accurate models of human body parts (Figure 1; PrimalPictures.com©). While this provides an excellent opportunity to graphically illustrate the physiology and anatomy of the human form in 3D, recent studies show that the learning experiences of the students are variable (Lewis 2003, Granger and Calleson 2007). Early detection of these warning signs may therefore provide evidence that in some instances Engineering should not follow suit. However, growing student numbers in Engineering has also resulted in wide-spread use of computer simulations, videos and virtual laboratories to replace hands-on practicals and face-to-face teaching opportunities (Bourne et al 2005). In addition, the new generation of students, generation-Y, tend to trust the information that they receive through the multimedia means of education and feel themselves more comfortable with the e-learning techniques (Khine et al. 2003).

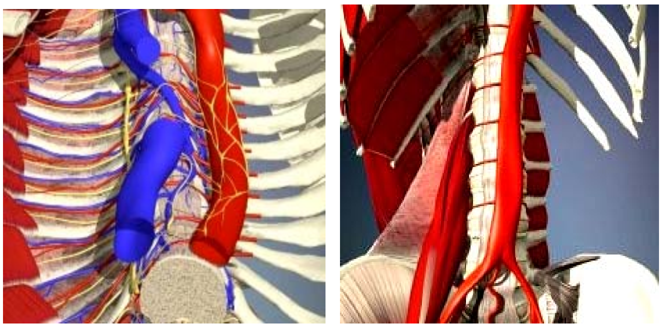

Figure 1: Virtual Anatomy (PrimalPictures.com)

In the past, the learning needs of engineering students have not been met satisfactorily by online education (Bourne et al, 2005). This was primarily due to the difficulty in implementing mathematical equations online, the difficulty in providing remote laboratory sessions and the appeal of direct operation of instruments (Grose, 2003). However, the delivery of Engineering education has been redefined by the advent of worldwide network capabilities and there has been a vast amount of research that favours a blended mixture of online learning in support of traditional face-to-face teaching methods (e.g., Ross and Scanlon, 1995; Fernandez et al., 2002; Saliah-Hassane et al., 2002; Fruchter and Townsend, 2003; Richardson and Swan, 2003). Online education has been claimed to increase flexibility of study, ensure student satisfaction, facilitate knowledge of contemporary issues, allow bringing distant experts into the virtual classroom, enable access to remote resources, permit organising groups of learners from geographically dispersed locations, and assist in building lifelong learners (King, 2008). Implementation of online learning is not free from misconceptions, however. Distance learning does not necessarily bring about student isolation (Richardson and Swan, 2003); in fact social interaction between students and instructors is a determinant factor for successful performance. Current debate focuses on whether the objectives of engineering education can be met to a sufficient degree online to allow accreditation (Bourne et al., 2005). This review paper explores the parallels in current learning trends that are adopted (or evolving) in both the disciplines of Engineering and Human Anatomy. We address the use of modern technology for distance and multimedia learning and discuss the advantages and disadvantages of either replacing or complimenting traditional “hands on” tangible pedagogical methods. It is envisaged that lessons can be learned and effective modes of delivery identified from comparisons across the disciplines of and Engineering and Anatomy.

Effective Paradigms of Anatomy Education

Human Anatomy is the cornerstone of many medical and allied health programs that exist throughout both Australia and the rest of the world and the traditional teaching model of lectures and dissection is strongly supported (Halperin 2007). However, this approach is being questioned due to: costs associated with obtaining human cadavers, increasing student numbers, reduction in teaching contact hours, introduction of peer teaching, fewer qualified anatomists, an explosion of educational research (use of prosections and plastination specimens), and development of online and multimedia learning packages including computer assisted learning (CAL) and PBL approaches (de Jonge et al 2008). Currently there is considerable debate as to ‘best practice’ in teaching Anatomy at tertiary level and very few reviews of delivery modes conclude which method produces the best student outcomes. Two reviews on the topic (Lewis 2003, Winkelmann 2007) failed to pool common trends of good practice. However, a more recent study (de Jonge et al 2008) conducted a systematic review of research papers that considered effective delivery modes of Anatomy educational material. In total 65 studies up to June 2007 were examined, from which only 40 met the inclusion criteria (randomised controlled trials and National Health and Medical Research Council (NHMRC) critical appraisal tool score on hierarchy of evidence; NHMRC 1999). The data from these 40 studies was pooled in a meta-analysis using Review manager software. We take the review of de Jonge (2008) further and systematically compare the following pedagogical methods.

Traditional lecture and dissection approach versus PBL: In two studies which compared student test scores and perceived Anatomy knowledge from eight medical schools there were conflicting results as to the effectiveness of PBL approaches. Prince et al (2003) found no significant differences between teaching methods, whereas Hinduja et al (2005) showed that students from traditional schools scored significantly higher than those from courses using PBL approaches. However, it should be noted that the top scoring medical schools generally dedicated a greater amount of time to teaching (including repetition) than other less high scoring schools (de Jonge et al 2008).

Dissection versus prosection: The work presented in the systematic review by de Jonge et al (2008) found that no one technique was advantageous towards student test scores. Student satisfaction varied with no clear bias as to dissection or prosection techniques. However, it should be noted that the use of prosections did conserve cadavers and reduce contact hours for staff and students.

Traditional dissection versus peer teaching: Results of an early study indicated that peer teaching was reported to save time and yet also gain high student satisfaction as more time became available for personal study (Bernard, 1972). However, no recent study managed to produce any data that could statistically support or refute the different teaching approaches to student learning (e.g., Nieder et al, 2005).

Traditional teaching versus multimedia-aided learning: This is an area that is common to many disciplines within education and is currently receiving considerable attention in both Anatomy and Engineering disciplines (Biasutto et al 2006, Bourne et al 2005). The systematic review of this area revealed seventeen studies that had compared traditional and multi-media methods of teaching. The traditional method consisted of the lecture and tutorial followed by laboratory practical class. Multi-media was defined as including the use of videotapes, discs, slides, audiotapes and computer packages (web based or not). However, many of the studies reviewed included content areas and course lengths that varied considerably and thus much of the data was unable to be pooled in any meta-analysis. Mayer (2005) suggests that people can learn more deeply from the words and pictures which can be defined as the basic concepts of multimedia learning.

Different types of CAL: From the systematic review of de Jonge et al (2008) it is evident that seven studies specifically investigated the choice of CAL within Anatomy education. Three of the seven studies reported positive results for the use of CAL. Devitt and Palmer (1999) compared the use of three different CAL modes (problem solving, didactic and free text) with a control group to teach the anatomy of the biliary system. The results concluded that all groups improved their test scores, with the didactic CAL group improving significantly more than the other two groups. Sultana et al (2001) examined the use of a video package compared to the use of a CD ROM package for teaching pelvic anatomy in two groups of participants. The results indicated that both groups had improved their test scores following exposure to these techniques. Finally, Nicholson et al (2006) showed that the use of a 3D computer model to teach the anatomy of the middle and inner ear significantly improved student test scores. However, it should be noted that there were limitations in the application of these studies; that is, the participants were already high achieving medical students, the data was difficult to pool, and some test results did not contribute to final grades. Most importantly, no study reported that the use of CAL was detrimental to student learning, which suggests that it may be useful as an adjunct to conventional student learning techniques. De Jonge et al (2008) reported that other studies went further into their investigations of CAL. These studies (e.g., Levinson et al, 2007) compared such elements as multiple-view versus key-view learning in which it was concluded that multiple view learning may actually impede some students who have poor spatial recognition. Learning style (self instruction and slide/audio) did not predict preference for instructional method but students did prefer the web based format to the use of the slide/audio tape approach (Fleming et al 2003). One study examined the use of web-based resources in association with grades obtained (Rizzolo et al 2002). Twenty students who scored the lowest had accessed the web-based resources for the course significantly less that the middle and top 20 groups. Cooperative quizzes out-performed individual quiz scores, but students were clearly supportive for both types. Finally, the summative effects of structured learning activities (student teaching assisted programmes, directed study, laboratory reviews and web based programs) made some contribution to the improvement in students practical exam scores (Forester et al, 2004).

Summary of Anatomy education: From the review above, it is clear that no individual or clear combination of teaching delivery modes in Anatomy is consistently better at developing improvements in student grades. However, there are both time and cost saving advantages in the application of some systems (e.g., prosections versus cadavers). Also, the use of CAL tools (video, CD ROM, 3D models, Web format) has proven effective. (Many of the studies reviewed, however, were open to significant limitations (non-random populations, non-blind studies, weak pooling of study data, no moderation of marks and outcomes, and biased samples -high achieving medical students).

Effective Paradigms of Engineering Education

In a recent report (King 2008) commissioned by the Australian Council of Engineering Deans and which was supported by Engineers Australia, The Academy of Technological Sciences and Engineering, The Australian Association for Engineering Education, and the Australian Learning and Teaching Council, Emeritus Professor Robin King addressed the issues surrounding the need for the supply and quality of Australian engineering graduates for the 21st Century. Support for the original work was provided by The Australian Learning and Teaching Council, an initiative of the Australian Government Department of Education, Employment and Workplace Relations. The report conducted a detailed review of the Australian Engineering education system which included many examples of good practice in different modes of teaching delivery. The report of King (2008) has been used in the present review to compare Anatomy and Engineering teaching models. In particular, the focus is on recommendation three (page iv):

> ***Recommendation 3:*** *Implement best-practice engineering education. Engineering schools must develop best-practice engineering education, promote student learning and deliver intended graduate outcomes. Curriculum will be based on sound pedagogy, embrace concepts of inclusivity and be adaptable to new technologies and inter-disciplinary areas.*

The report identifies current directions for best practice in Engineering curriculum design and implementation within Australia, with particular emphasis on active learning (including PBL and Project Based Learning). King (2008) also discusses the use of remote access laboratories; project centred curricula and improved assessment methods. Figure 2 shows the traditional approach to Engineering education as identified by Engineers Australia. The figure shows the classroom and laboratory setting expanding to the entire program being delivered by distance education and online systems. The campus (University) boundary is shown in the diagram as that which contains classroom, laboratory, reflective learning and research education. Beyond the boundary, industry placements, and internet and distance learning are suitable alternatives.

Traditional lecture and laboratory class approach versus PBL: Currently there are two Universities within Australia (University of Central Queensland and Victoria University) which use PBL for their entire undergraduate Engineering curriculum (Stojcevski and Velijanowski 2007). Experiential and active learning is seen as the pre-eminent method needed in order to craft pre-professional behaviour in graduates. Such courses as Engineering principles and Design Graphics which are introduced at first year level are ideal in developing such experiential learning. Thus, it is evident that focus should be placed on the learning attributes of the students. For example, generation Y students learn better from active learning approaches such as PBL (Stojcevski and Velijanowski 2007). There was, however, a specific role for the lecture and the laboratory practical class but these should not dominate activity. The interaction between students and instructors has been identified as a determinant factor for successful online learning which also enhances the students' experience (King, 2008). Finally, research by Willey and Freeman (2006) has shown that positive learning outcomes could be achieved through active participation, such as peer review and assessment.

Traditional on-campus vs. online degrees: Mathematics and Science has lagged behind in the development of online venues (King, 2008). In fact, Mathematics and Science are traditionally perceived as the hardest to teach online due to the need for labs and equation manipulation. Nonetheless, Sener and Stover (1997) observed similar learning effectiveness when using physical hands-on labs and virtual remote labs. Similarly, Richardson and Swan (2003) reported no significant differences in learning outcomes between on-campus and online students, as measured by test scores. At present, the adoption of online degree programs remains low mainly because remotely controlled physical labs are expensive to implement online. Solutions put forward include the sharing of high costs amongst institutions and improved interactivity between educators and students. Recent observations (Theroux, 2004) have also revealed that equations are much easier to deploy with current technology tools.

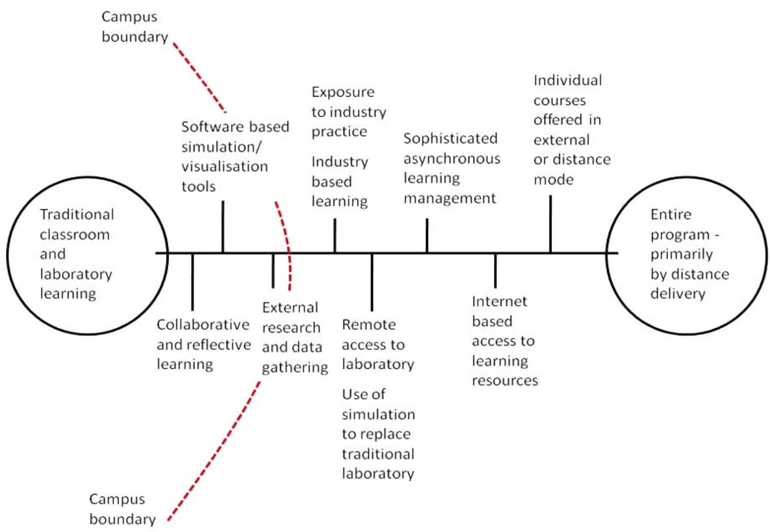

Figure 2 – Traditional approach to Engineering Education from the report to the Australian Council of Engineering Deans (Engineers Australia 2008).

In agreement, Bourne et al (2005) has pointed out that students working at a distance but assembling in person for lab sessions may provide a good method for blending online with hands-on learning. A recognised value of blended degrees is their capacity to build lifelong learners (Theroux, 2004) whereby students 'learn to learn', by using educational methods they will use throughout their professional lives. Bourne et al (2005) has presented a rationale for the benefits of online Engineering education in augmenting Engineering competencies and accreditation. Online systems and the use of the internet can provide: increased availability of Mathematics and Engineering problems, access to remote resources, capability to work with selected industries and to design components that meet the manufacturer's needs, capacity to function in multidisciplinary teams, added real-world experiences to identify and solve problems, increased written communication (asynchronous system), and global capability and thus the milieu in which lifelong learners of engineering will work throughout their careers. In particular, it is emphasised that the use of off-campus modalities while still on campus will assist transition to lifelong learning, and that the use of the internet promotes knowledge of contemporary issues. In addition, many engineering tools are internet based and hence the use of internet allows access to such modern techniques and engineering tools. An example is found in a recent internet-based Engineering project undertaken by two of the authors of this paper (Marqués-Bruna and Grimshaw, 2009) in which computer-aided-design (CAD) and mathematical tutorials are used for the modelling of the inertial properties and computation of the flight trajectory and flight stability of the ski jumper, and the reconstruction of the jumping hill profile.

The blending of methodologies: Blending methodologies is perceived as an optimal combination of face-to-face and online education (Fernandez et al 2002) that increases learning and student and instructor satisfaction. Specifically, Saliah-Hassane et al. (2002) has reported that blending educational methods saves on classroom use and lab time, generates convenience, allows bringing distant experts into the classroom, and permits organising groups of students located in different places. Teaching online can be implemented via different pedagogies. In synchronous broadcasting, lectures are viewed 'live' as they take place, and can also be recorded for later playback. Electronic tools can be made accessible in a geographically dispersed learning environment. Modes of assessment and rapid feedback based on scores can also be secured online. To add support to these arguments, the work of Fruchter (1991, 2002) concluded that no significant difference in test scores and satisfaction surveys exists between fully face-to-face and fully online courses; with the benefits of online learning including not missing a session by attending remotely, possibility to review a recorded session, and time shifting with an asynchronous session. It is suggested that learning outcomes can be improved by online simulations, visits from remote luminaries, provision of cross-institution learning experiences, and improved communication among students (Grandzol, 2003). Also, provision of self-paced modules (to learn the basics) allows additional time for instructor-led courses and interactive exercises.

Experimental and laboratory work in engineering: Engineers Australia place specific emphasis on Engineering application skills development and this includes laboratory and practical capabilities with emphasis on the scientific method (experimental design, test and verification). All Engineering consultancies reported in the report by King (2008) were in favour of retaining and indeed strengthening the practical content of Engineering programs. However, one issue that arose from consultation with students was that laboratory experiments should be more about testing validity of design rather than proving scientific fact. However, there are widespread concerns about Universities abilities to staff and fund practical laboratory work. Remote laboratories and software simulations have raised concern over their application, but when administered properly these can increase learning value (King, 2008). In Engineering, simulations allow students to explore problems that are beyond what is available in the physical environment.

Generic graduate attributes: Graduate attributes, or generic capabilities, within Engineering education consist of such qualities as problem solving, communication, teamwork, ethics and lifelong learning, which are supported by industry (King, 2008). While Engineering students respond positively in their reflective judgements on attainment of generic skills, criticisms from industry and the business community provide clear evidence of a wide variation in the promotion of these skills across courses (King, 2008). In addition to such a perception of the graduate attributes by the stakeholders, universities define different core attributes with the different levels of prioritise, hence, the graduates of the education system do not have similar capabilities. Most common criticism of graduates include that modern graduates have poor communication skills (particularly in business-specific writing), lower grasp of the fundamentals, less ability to work from first principles, are heavily reliant in software tools, and are unable to independently validate computer answers. In contrast, employers tend to agree that today's Engineering graduates are better at oral communication, better team workers than their predecessors, and comfortable in the use of software tools. A meta-analysis produced by the former Carrick Institute showed that a lack of good teaching and assessment methods was one of the main 'hurdles' towards the development of these attributes (King, 2008). Finally, in some cases there was conflict between what was seen as university graduate attributes and Engineering graduate attributes. Perhaps, graduate attributes need to be embedded in the curriculum rather than taught directly (Carew and Threse 2007; Crawley et al 2007).

Curriculum inclusivity: The engagement of women within engineering education is a problem that is probably unique to this discipline. King (2008) reported that students have observed that Engineering curricula (and physical science texts) tend to be crafted with over-use of masculine stereotypes and examples (automobiles, rockets and weapons). It is, however, clear that all elements contained within an Engineering curriculum should be as equally suited to women as they are to men. Solutions to this problem include the use of analogies that relate better to females than to males. One such example within Australia was the use of a 'blood pump' rather than an automobile fuel pump which increased female students' understanding of relevant mechanical principles yet had no change to the level of understanding which was acquired by males.

New methodologies and directions for innovation: The introduction of remote labs and the increasing use of software simulation have raised concerns amongst some academics and members of industry who expect students to practice with real hardware as well as engage with underlying theory, simulation, and full-scale implementation of Engineering systems. However, King (2008) assures that when properly administered remote labs can add learning value. Gillet et al (2005) agrees that modern Engineering educational demands pose challenges to traditional academic institutions including pedagogical, technological and organizational. The transition towards a flexible education scheme necessitates flexible access to experimentation resources (Schmid, 1998; Magin et al, 2000) and to collaboration facilities. From a logistical viewpoint, collaborative web-based learning supports the handling of larger classes in a context where financial means to equip laboratory premises is limited. The most frequent positive comment of a pilot scheme of flexible web-based Engineering education was, in fact, its flexibility (Gillet et al., 2005). Students commented that internet learning had provided them with an excellent choice to perform hands-on activities at any time and from any location. Students favoured the inclusion of all the necessary tools in one integrated environment and thought that the interactive hands-on activities reinforced their theoretical knowledge. In particular, the students favoured the use of an eJournal as a convenient medium that allows interaction across learning modalities and among members of the learning community (Gillet et al., 2005). The majority of negative comments concerned technical problems (server crashes), the complexity of the interface (many windows and many tools), and no provision of satisfactory help. In the flexible learning context, the attempt to introduce synchronous collaboration tools, such as chat facilities, were not successful since students preferred to meet and interact directly when they meet in campus. Students are also more comfortable discussing equations and graphics face-to-face, rather than using electronic tools. In terms of student attraction and retention, the typical Engineering curriculum is antithetical to the desirable attributes of choice, diversity and creativity. In contrast, online learning offers increased flexibility as lectures can be replayed at a later time (Ross and Scanlon, 1995), and generally opens more learning pathways as courses may be taken on-campus, online, onsite at a company, or using a combination of venues.

Mathematics and science in engineering education: Mathematics is contentious in the context of engineering education. Being able to manipulate mathematics in logical reasoning and to model the behaviour of physical systems are critical to understanding engineering analysis. King (2008) attributed the relatively high attrition rates in Engineering to the failure in mathematically intensive courses in the early years of study. Practising engineers asserted that the university mathematics was a "waste of time" in that they never used the advanced techniques they were taught. Other respondents stressed that it is important for engineers to understand the mathematics fundamentals behind the software tools they use, and to have the ability to validate computations (intuitive estimation). Further work by King (2008) indicates that students agree that mathematics topics should be delivered using examples from Engineering. Also, the students endorsed the formal, rather than self-learned, introduction of a suitable mathematical and modelling software program such as MATLAB®. In consulting faculty deans, different aspects could improve the effectiveness of mathematics and statistics in Engineering (King, 2008): team-teaching between Mathematics and Engineering, collaborative curriculum design, the use of common nomenclature, and a possible inversion of the curriculum to provide the high levels of mathematical content in later years, rather than during the initial years. The science component of Engineering programs raised much less discussion than mathematics. Also, low female participation of women in Mechanical and Electrical Engineering was attributed to the general dislike and low participation in school Physics by women.

Importance of engineering practice: Every consultation with student, industry and academic groups carried by King (2008) affirmed the value of good industry experience during the undergraduate program. However, many Engineering Schools have varying numbers of students unable to gain suitable work experience before the end of their course. A range of approaches may be adopted including formal industry-based learning programs that are well regarded by industry and students, cooperative schemes where students spend time in industry, arrangements for final year projects to be sourced from industry, organization of visits to Engineering sites (however these may be time-consuming and expensive). Also, industry professionals may be encouraged to provide guest lectures, or even run whole courses, although that the latter is not particularly easy for Universities or industry to manage.

Summary of engineering education: In summary, students appreciate the value of active participation and assessment in the form of PBL and peer reviews. Typical on-campus can be as effective as online learning, although blending these two methods in an integrated environment adds flexibility and convenience. Inclusion in Engineering can be improved by finding examples that appeal to female students. The impact of Mathematics may be ameliorated by using applied examples and formally introducing modelling software. Thus, this review on current Engineering education methods clearly points towards an integration of old methods and new technology and ideology.

Discussions and Results

Commonality and trends of good practice: Table 1 summarises the main findings of the comparative analysis between learning methods for the two disciplines of Anatomy and Engineering. There is no strong statistical rationale for disallowing traditional teaching methods for the teaching of Anatomy, based on scores obtained by students. It is clear, however, that there are advantages in the use modern pedagogical systems complimentary to traditional methods; for example, prosection helps save resources (de Jonge et al., 2008) and peer teaching is less time consuming and leads to student satisfaction (King, 2008). Tangible improvement in academic performance when using modern learning systems is more obvious in Engineering. There are perceived advantages, as reported by students, in the use of modern learning paradigms. Students approve, for instance, of active participation, PBL and active assessment (Willey and Freeman, 2006), and of strategies that improve inclusion of female students (King, 2008). However, other studies have found similar effectiveness when comparing on-campus and online study (Fruchter, 1991, 2002; Sener and Stover, 1997; Richardson and Swan, 2003). The present analysis, therefore, suggests that students perceive certain advantages in the use of modern learning models in both disciplines, Anatomy and Engineering, which may lead to student satisfaction and enjoyment of the course, and thus to related effects including motivation, retention and better preparation for professional life. The work of Devitt and Palmer (1999), Rizzolo et al (2002) Nicholson et al (2006) and de Jonge et al (2008) provides strong support for the use of specific CAL systems. Students favour and perform better when using video and CD ROM packages, computer 3D models, didactic methods, web-based formats and when working cooperatively. Multiple views of complex anatomical areas such as the brain and carpal bones using online systems can noticeably hinder the learning. This is obvious in students with poor spatial abilities. In comparison, little research has been conducted on the use of specific CAL methods in Engineering. It is evident that the strong desire for practical work in Engineering education is not likely to abate, even if the use of lab tools is limited to remote operation.

Generation-Y and learning: The Generation-Y refers to the current generation of university undergraduates as well as their peers who may not be involved in tertiary education. This generation, in contrast to the generation X who, in general, learnt the technology, has grown up with the technology and consider computers and communication through the network part of their life and society. 20% of them began using the computers between the ages 5-81 and virtually all of them were using the computers by the time were they were 18 years of age (Oblinger et al. 2005). It is well known that learning is a constructive process not a process of adding new information. In fact, for generation-Y with the free and facilitated access to the information through their network, the temp and amount of received information is exceeded the ability of learning for understanding. The concept of rote learning and meaningful learning has been discussed by Sweller (2005), where he describes the process of learning as transferring the information from the working memory to the long-term memory. It can be concluded that due to the limitation of the working memory with dealing with new information a generation-Y relies on the trial and error method for solving a problem instead of analytical approach which improves learning for understanding in contrast with bulk learning.

Lectures and generation Y: Although the technology is considered as a vital element in the education process, it shouldn't be cantered in the process of learning and learning process should be designed based on learner needs. It is understood that except the teaching material prepared based on the students needs and specialisation, learning is based on motivation, discussion and collaboration, planned based on the students social needs. This understanding fits with a social constructivist approach to learning. Social Constructivism was first advanced, by Russian psychologist and philosopher Lev Vygotsky (1980) as a theory of learning which emphasises context as an important aspect of constructing knowledge and meaning. Being bombarded with the massive and bulky type of information, generation-Y students are characterised of struggling with organising and analysing the information that they receive. For them a lecture and lecturer is another source of information in parallel with the internet based resources. In the process of tearning for the, the learning environment is replaced by the social networks such as Facebook and communicating through e-devices. Context refers to the situation in which the learning takes place, including the learning environment and the social relationships involved, for example between learner and learner, learner and teacher: knowledge becoming meaningful through social activity.

Future work

Despite recent improvements in the Engineering education system, there are continuing concerns with the methodology and effectiveness of modern learning trends. To ensure that graduate engineers attain the desired qualities, further curriculum changes and development will be essential to maintain student numbers, meet students' expectations and satisfy employers (King, 2008). Bourne et al (2005) has discussed suitable course of action to facilitate online learning and the effectiveness of such recommendations may be evaluated in future research. Further application of the computers, having access to better technology, number of students, and the paradigm shift in higher education (Chang et al. 2001) require a better understanding of the efficiency of already implemented method: virtual environment for learning practical sciences. Thus, institutions should aim to reduce costs (by sharing simulations and learning materials), increase student satisfaction (using step-by-step instructions for students that need additional help; providing opportunities for students to explore outside the confines of the classroom), allow rapid feedback (such as self-testing quizzes), develop a sense of community built from online discussions, provide mathematics and design capabilities (modern equation editors, Theroux 2004; system diagrams for electronic and mechanical design; capability for import and export between tools; concept maps, Rumble 2001), improve lab facilities for online Engineering education (web-based simulations), and increase faculty satisfaction and recognition. Such future research should endeavour to overcome the methodological limitations of previous studies and use standardised content areas and course lengths, and suitable data pooling for meta-analysis.

Table 1: Comparative analysis of learning methods and identified paradigms of good teaching practice.

Discipline	Type of comparison	Comparison of learning methods	Authors	Differences found?	Paradigms of good practice
ANATOMY	Traditional vs. modern learning methods	Traditional (i.e., lectures & dissection vs. PBL)	Prince et al (2003) Hindja et al (2005)	Yes	Extended teaching time & repetition
		Dissection vs. prosection	de Jonge et al (2008)	No	Prosection saves resources
		Dissection vs. peer teaching	Bernard (1972)	Yes	Peer teaching (time saving, student satisfaction)
		Traditional vs. multimedia	Biasutto et al (2006) Bourne et al (2005)	No	None identified
	CAL	Control? vs. video/CD ROM packages	Sutton et al (2001)	Yes	Video & CD ROM packages
		Control? vs. 3D model	Nicholson et al (2006)	Yes	Computer 3D models
		Problem solving vs. didactic vs. free text	Devitt and Palmer (1999)	Yes	Didactic approach
		View (multiple vs. key)	Levinson et al (2007)	Yes	Key view (for students with poor spatial recognition)
		Learning (self-instruction vs. slide/audio)	Fleming et al (2003)	No	Both methods show similar learning effectiveness
		Format (web vs. slide/audiotape)	Rizzolo et al (2002)	Yes	Web-based format preferred
		Quizzes (individual vs. cooperative)	Rizzolo et al (2002)	Yes	Cooperative learning

Discipline	Type of comparison	Comparison of learning methods	Authors	Differences found?	Paradigms of good practice
ENGINEERING	Traditional vs. modern learning methods	Traditional (lectures vs. PBL)	Willey and Freeman (2006) Stojcevski & Velijanowski (2007)	Yes	Active participation (i.e., PBL) Active assessment (i.e., peer reviews)
		On-campus vs. online	Fruchter (1991, 2002) Sener & Stover (1997) Richardson & Swan (2003)	No	Both methods show similar learning effectiveness and learning outcomes
		Graduate attribute emphasis (problem solving vs. communications vs. team work vs. ethics vs. lifelong learning)	Carew and Threse (2007) Crawley et al (2007)	Yes	Use of good teaching and assessment methods
		Male vs. female analogies	King (2008)	Yes	Inclusion of female analogies
		Traditional vs. flexible web-based learning	Ross & Scanlon (1995) Gillet at al (2005)	Yes	Integrated learning environment
	Theoretical vs. practical	Traditional vs. applied Mathematics	King (2008)	Yes	Use of applied Eng. Examples Use of suitable Math and modelling software
		Theory vs. practical work	King (2008)	Yes	Exp. testing of design validity Remote labs and simulation

Conclusions

This review paper discusses parallels in emerging learning methods and identifies paradigms of good learning practice within Human Anatomy and Engineering education. Although learning modalities have evolved independently in both disciplines, modern interdisciplinary degree programs such as the new degree in Sports Engineering at the University of Adelaide require an effective blend of learning models to ensure student performance and satisfaction, fulfilment of industry requirements and institution recognition. The findings point towards a harmonious blend of traditional and online remote web-based learning methods, where it is crucial to be attentive to student preferences in learning modality.

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