Exploring synergies between learning and teaching in engineering: A case study approach *

W Boles †
Queensland University of Technology, Brisbane, Queensland

R Hadgraft
The University of Melbourne, Melbourne, Victoria

P Howard
CQUniversity, Rockhampton, Queensland

SUMMARY: *Understanding how we take in, process and present information as part of the learning process, provides clues on how specific teaching methods can be utilised to maximise learning. The literature suggests that a mismatch between learning styles or preferences and teaching styles and approaches may present a barrier to learning and contribute to attrition. This paper presents some early findings of an Australian Learning and Teaching Council (ALTC) Associate Fellowship program, involving three universities, which uses a case study approach to explore the interactions between students' learning styles on the one hand, and lecturers' teaching styles, goals and philosophies, on the other. The paper also initiates discussions on how teaching approaches may be tailored to address the diversity of students' learning styles over the duration of the engineering program, to enhance their learning experience and outcomes.*

1 INTRODUCTION

One of the major challenges currently facing Australia is the skill shortage in engineers (Engineers Australia, 2006). In a media release ahead of the Australian Technology Network of Universities conference, held in Perth in 2008, the Chief Executive of Engineers Australia (Taylor, 2008) warned that there is an estimated shortfall of more than 20,000 professional engineers to meet current demand in Australia.

The final report on the Australian Learning and Teaching Council (ALTC) funded project sponsored by the Australian Council of Engineering Deans (ACED) pointed out that there is increasing and widespread concern that the current high demand for engineering graduates is not being met by corresponding increases in student demand for engineering education programs (King, 2008). Considering retention rates of engineering students and based on data obtained from the Department of Education, Employment and Workplace Relations (DEEWR) via Engineers Australia, the report indicated that the likelihood of successful graduation from a bachelor level engineering program is about 52% for male Australian engineering students and 60% for female students, on average.

Therefore, while there is increased demand for engineers, it is not being matched by an increase in the demand for engineering programs. At the same time, of the small numbers entering engineering programs, only a shockingly low percentage actually graduate. This means that, more than ever before, maximising retention rates of students in engineering programs is of critical importance.

To support and facilitate student success rates and engender active learning, there is a need to have a commitment to identify and respond to weaknesses in teaching, as well as student understanding, within a cohesive and comprehensive program.

To retain students and evaluate the success or otherwise of their programs, universities routinely conduct surveys and collect data. However, it is vital to have sophisticated program evaluations that

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† Corresponding author Wageeh Boles can be contacted at w.boles@qut.edu.au.

are well documented with thorough analysis of the data they provide. It has been observed that in data collected via the Course Experience Questionnaire (CEQ), students may rate all aspects of teaching as being of high quality, yet they score the whole course/program's experience as being poor. Such a dichotomy highlights the need to have a closer look at survey questions, other feedback and data collection mechanisms to gain insights into factors affecting engineering students' perceptions of quality teaching, and to discover the reasons that contribute to their success. There is a need to share research results in order to assist in engendering a productive discussion on the matter.

This paper presents an overview and some results of an ALTC Fellowship program being undertaken to bridge the gap between students and academic staff in engineering. The program aims at enhancing the learning experience and learning outcomes of engineering students, and embedding enabling strategies and processes for engaging engineering students and staff, systematically. It focuses on exploring synergies between learning and teaching. The paper reports on a case study approach for investigating the interactions between the learning styles of students on the one hand, and the teaching styles of academics, their teaching practices, and their teaching philosophies, on the other.

2 LEARNING AND TEACHING STYLES

Research shows that students are characterised by significantly different learning styles: they preferentially focus on different types of information, tend to operate on perceived information in different ways, and achieve understanding at different rates. The work of Felder & Silverman (1988) on learning and teaching styles in that discipline is a relevant example of the value-adding the discipline-based approach continues to deliver for engineering. Students whose learning styles are compatible with the teaching style of a staff member tend to retain information longer, apply it more effectively, and have more positive post-course attitudes toward the subject than do their counterparts who experience learning/teaching style mismatches (Felder, 1993).

In a recent study of the various learning styles, Coffield et al (2004) questioned the validity and reliability of the learning styles construct and assessment instruments. However, in discussing the implications for pedagogy, they stated that:

> *"A knowledge of learning styles can be used to increase the self-awareness of students and tutors about their strengths and weaknesses as learners. In other words, all the advantages claimed for meta-cognition (ie being aware of one's own thoughts and learning processes) can be gained by encouraging all learners to become knowledgeable about their own learning and that of others."*

Coffield et al (2004) referred to the work of Apter (2001), who suggested that an understanding of the various factors that affect or result in different motivational levels, given the possibly different contexts, can "allow people to become more in control" of their own motivation and of their learning, as a result. Coffield et al (2004) related that Apter continued to state that:

> *"Learners can become more effective as learners if they are made aware of the important qualities which they and other learners possess. Such knowledge is likely to improve their self-confidence, to give them more control over their learning, and to prevent them attributing learning difficulties to their own inadequacies."*

Through the case studies, this program provided an opportunity for participating students and lecturers to engage in meaningful discussions about learning and teaching styles.

When Grasha (1994) started his investigation into teaching styles, he made the assumption that a teaching style represented a pattern of needs, beliefs and behaviours that lecturers demonstrated in their classroom. He also envisaged that style was multidimensional, and affected how lecturers presented information, interacted with students, managed classroom tasks, supervised coursework, introduced students to the study area or profession and mentored students.

The interaction between the students learning styles, lecturers' learning styles, teaching styles and philosophies provides a rich field for investigation and holds a great potential for enhancing students' learning environment and outcomes.

3 THE CASE STUDIES

The case studies have a primary focus on the learners (students), the teachers (lecturers) and the learning environment (institution). They are designed to explore the proposition that a mismatch between learning styles, teaching styles and institutional norms may impede student commitment and success in learning. By institutional norms we mean such factors as the prestige attached to research, the dominant model of delivery (whether it be lecture, online, project, etc.) and the amount of support offered to students in adjusting to university culture.

3.1 Case study protocol

The sites chosen for the case studies reflect a range of institutions whose cultures could be expected to have an impact on students' ability to learn how to learn. One is a traditional sandstone university (The University of Melbourne), one is a technological university (Queensland University of Technology, QUT) and one is a regional university

(CQUniversity). In each site, two major activities were implemented: one with students, the other with lecturers. The program worked with current students and staff across the three universities, to study this gap (between students and lecturers) by modelling a process of investigation, analysis, problem-solving, pedagogical design and implementation that develops a culture of shared responsibility between students and staff for creating learning outcomes.

Students were asked to complete a learning styles survey and participated in focus groups. Volunteering lecturers were asked to complete a learning styles survey and a teaching styles survey. In addition, an instance of their teaching was observed and they were also interviewed. The student focus groups and lecturers' interviews assisted in obtaining an insight into the effects of the institutional culture. Figure 1 illustrates the elements of the case study and draws attention to their interconnectivity.

The learning styles instrument chosen is Felder and Silverman's Index of Learning Styles (ILS; Felder, 1999), since it was developed for engineering students and was used in previous studies such as the one reported by Mills et al (2005). The ILS uses four dimensions to describe learning preferences. Each preference is rated on a scale from 1 to 11, with 11 being the strongest preference. The four dimensions can be described as in Mills et al (2005):

1. *Active/Reflective*: This dimension refers to processing of information. Active learners prefer trying things out and working with others. Reflective learners prefer to think things out and work alone.
2. *Sensing/Intuitive*: This dimension refers to ways of receiving information. Sensors like learning facts and using tried methods in practical settings. Intuitive learners are innovative, and enjoy abstract concepts and new situations with untried methods.
3. *Visual/Verbal*: This dimension refers to ways of perceiving sensory information. Visual learners relate well to graphs, pictures, diagrams, etc. Verbal learners enjoy reading and lectures.
4. *Sequential/Global*: This dimension refers to progress towards understanding. Sequential learners prefer taking logical steps towards an outcome. Global learners grasp the big picture quickly and work out the steps later.

The teaching styles instrument used is that of Grasha (1994). This has five categories of styles, namely: Expert, Formal Authority, Personal Model, Facilitator and Delegator. However, Grasha (1996) claimed that all teachers possess each of the qualities of the five styles to varying degrees. In a thematic analysis of his experiences, he found that four combinations, or clusters, of styles were evident. Teachers use some styles more often than others or use styles in combination. He further identified four clusters as shown in table 1.

In addition to the learning and teaching instruments, academic staff are invited to use T. Angelo and K. P. Cross' Teaching Goals Inventory (Angelo & Cross, 1993) to help reflect on their self-assessments of teaching styles and actual interactions with students in the classroom.

Discussions of the immediate findings of the case studies formed the kernel of the workshops conducted at each of the participating institutions.

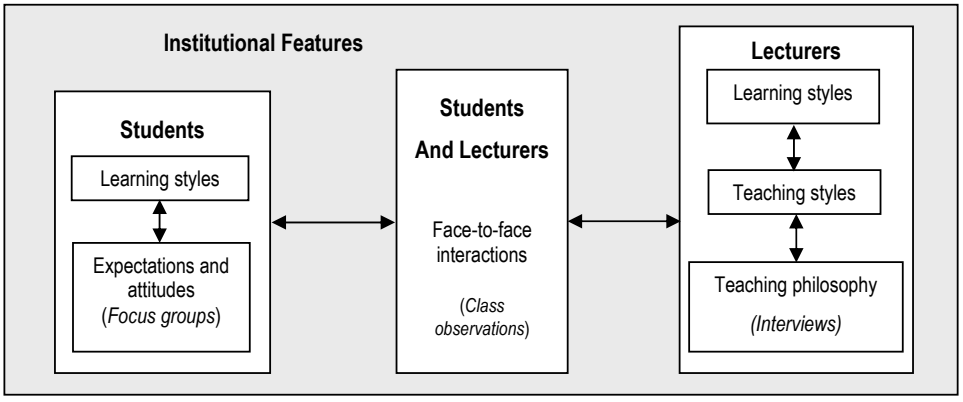

Figure 1: Elements of the case study.

Table 1: Teaching methods.

Cluster	Primary styles	Secondary styles
1	Expert/Formal Authority	Personal Model/Facilitator/Delegator
2	Expert/Personal Model/Formal Authority	Facilitator/Delegator
3	Expert/Facilitator/Personal Model	Formal Authority/Delegator
4	Expert/Facilitator/Delegator	Formal Authority/Personal Model

Since the literature suggests that making the learning process and its potential barriers explicit can help enhance outcomes, the workshop intended to encourage participants to work together towards this goal.

Feedback to participants and the discipline forms an important part of the program. Individual academic staff participants will be receiving a summary reflecting on their survey and interview results, and the findings of the observations. Where possible, this will be offered with some pointers and suggestions on how to move forward for creating a better learning/teaching nexus. Figure 2 describes the learning situation, linking pedagogical research with teaching, learning and institutional influence.

3.2 The process

At each university, a call for participation of academic staff was made via information sheets, discussions and presentations to staff. These varied depending on the circumstance of each institution. The timing of conducting the studies was largely determined by semester schedules, and staff and students timetables.

At CQUniversity, the Program Collaborator (Prue Howard) led the efforts of recruiting participants and organising staff interviews and class observation schedules. A parallel process was followed at the University of Melbourne, led by the Project Collaborator there (Roger Hadgraft). While leading the program, the ALTC Associate Fellow (Wageeh Boles), was in direct communication with colleagues at QUT via formal and informal meetings and discussions. In all cases, the Project Officer communicated with all involved, and organised and kept track of activities. The Project Researcher was in charge of conducting the class observations and staff interviews. In addition, at each institution, student focus groups were scheduled and conducted with volunteering students.

The ALTC Associate Fellow, the Project Researcher and Project Officer facilitated three workshops conducted at the participating institutions. In addition to disseminating the findings so far, the workshops aimed at engaging the participants in activities leading to the start of a process of change. In view of the learning and teaching styles, and the insights presented and discussed, the workshops focused on developing a process of critical self-evaluation and co-creation of more suitable pedagogies, and taking away a plan to apply in their own situation.

4 PRELIMINARY FINDINGS

At this stage, considering staff interviews and scores of the learning styles inventories, we are able to provide the following brief comments. It must be warned that these are not meant to provide foundations for any generalisations, given the small number of participants. However, the comments would be useful for initiating discussions around possible ramifications for student learning.

Regarding learning styles, while most staff rated themselves primarily as visual learners, on the visual/verbal scale (see figure 3), some staff rated

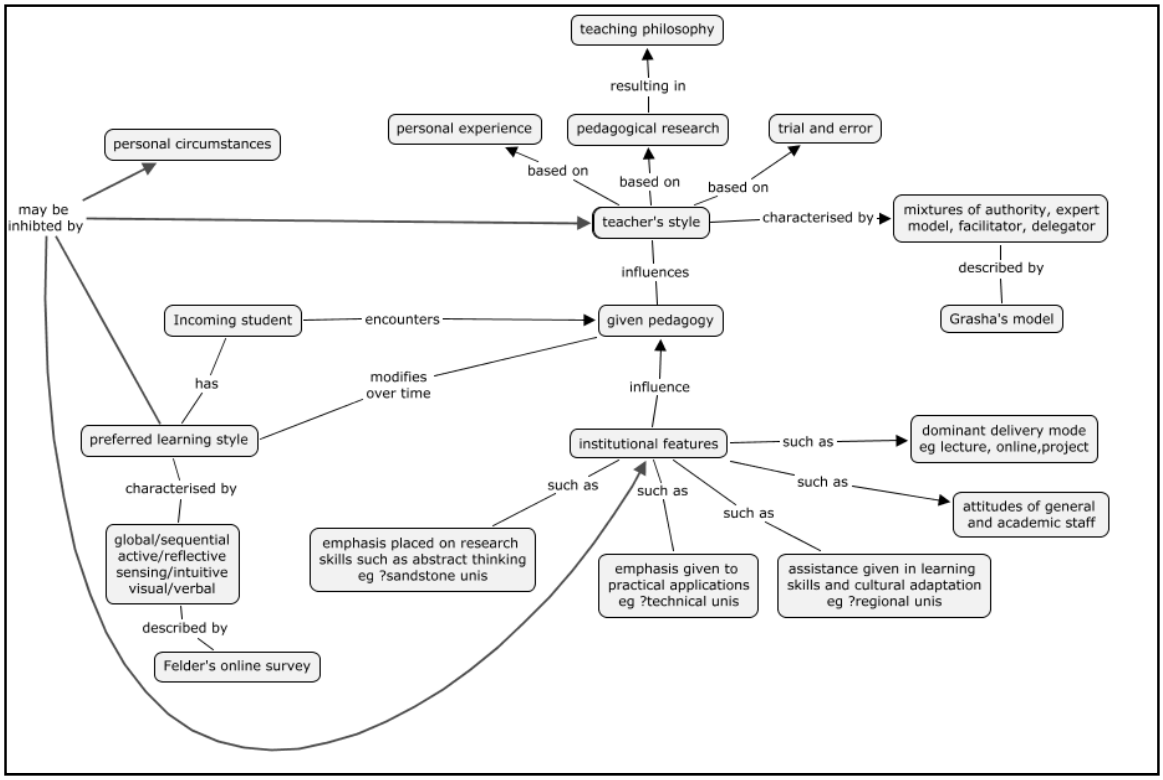

Figure 2: The learning situation.

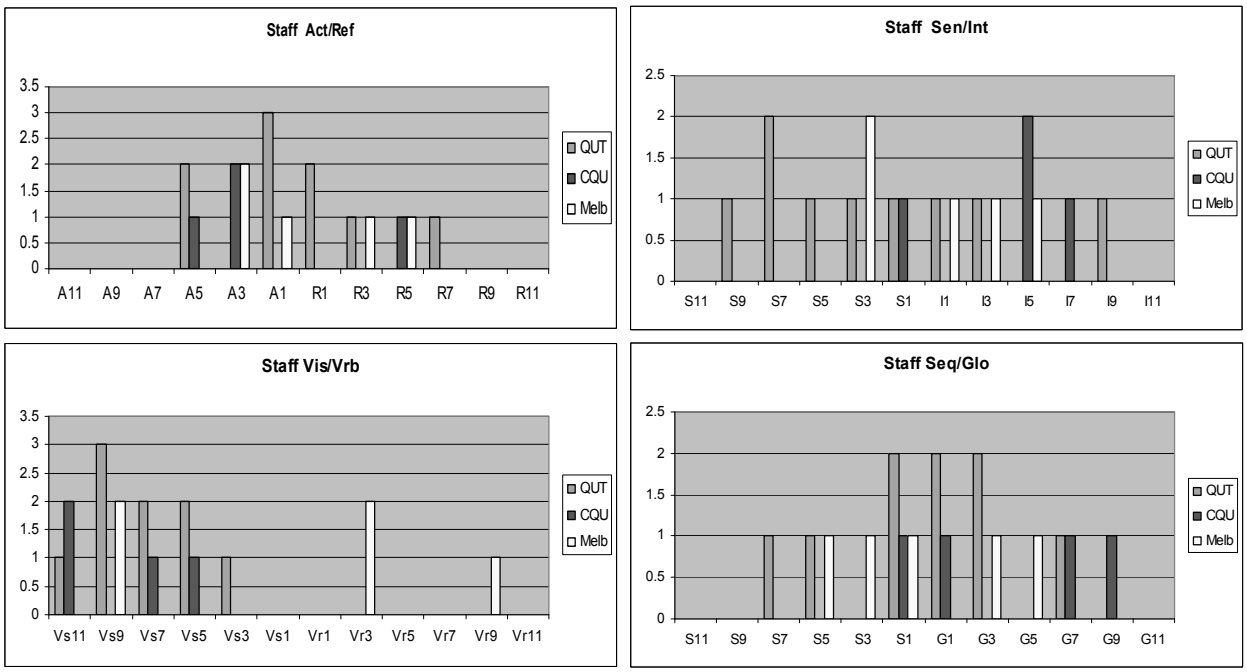

Figure 3: Staff learning styles (Act/Ref: Active/Reflective; Sen/Int: Sensing/Intuitive; Vis/Ver: Visual/Verbal; Seq/Glo: Sequential/Global).

highly on the verbal scale. This would highlight the importance of avoiding generalisations in describing learning styles and dealing with individuals as the case may be. This should also be considered when responding to students' survey data.

For the highly visual academic staff, the fact that they routinely prepare many excessively wordy PowerPoint slides represents a clear contradiction. However, this may meet students expectations if not preferences, given that students may have come to expect it, due to the way we traditionally teach.

Most of the lecturers interviewed at all three universities identified the style of teaching they were exposed to as students, as mainly a matter of content transfer. In discussing their aims almost all interviewed staff said that content transfer was primary. This stance is consistent with their scores on the teaching inventory as primarily Formal Authority. At the same time, many teachers seem to feel that they "ought" to be more interactive and this would not be helpful for Formal Authority styles in relation to imparting content. We could ask many questions about this data, including what counts as content, but at this stage we have not explored this. It seems that the primary influence on teaching style is personal experience, often without much reflection added.

Preparing people to work was rated as a goal by participating academic staff, although in one case study, the average time spent in the workforce outside of a university by staff is just over 4 years. This probably contributes to a fact-and-theory approach, although projects are much discussed. Added to this, the organisational requirements on staff to concentrate on research would further reduce the likelihood that they will spend time reflecting on or researching teaching issues.

Interviewed staff seldom resorted to professional advice or the education literature to address teaching matters. The lack of time to find and explore the literature and penetrate its jargon was most commonly cited as the reason.

The number of students who completed the ILS varied from one institution to the other, with QUT having maximum participation of 99, followed by Melbourne (48) and CQUniversity (9). One factor affecting the low participation rate at CQUniversity can be attributed to the fact that many students were at their industry placements at the time participation was solicited. Student responses to the LSI were broadly similar across the three universities with the only strong preference being on the Visual scale, with a lesser tendency towards Sensing on the Sensory/Intuitive scale. Combining the LSI scores of all student participants, the results did not generally differ from those reported by Mills et al (2005).

Students' learning styles results, together with comments they made through focus group discussions, demonstrated how staff aims, as expressed during their interviews, can affect student learning. For example, the modelling of engineering approaches observed in lectures is therefore likely to strike a chord with students who rate highly on the sensing scale. However, we would expect those students to be less happy with a highly unstructured approach to project work. This is in fact borne out by students' own comments in this study.

5 DISCUSSION AND CONCLUSIONS

For many students, achieving at university can be seen as attempting to complete an obstacle course. As teachers, our role is to set up realistic targets that challenge students to reach new heights in understanding and practice. But in some cases, set tasks become insurmountable barriers leading to student failure or attrition. In reviewing the literature on learning, and in particular on barriers to learning, three key areas emerge as being potentially challenging for students to such an extent that they may not succeed: conceptual barriers or barriers associated with the nature of our disciplines themselves; internal barriers and student characteristics; and external barriers. These barriers are obviously not independent of each other. It may be the case that a student who is underprepared mathematically for engineering study finds that their aspirations or motivations to become an engineer are eroded by classroom experiences. Such experiences can leave them feeling alone and isolated from the content they are studying, the academics that teach them and their fellow students.

Much of the literature on *student approaches to learning* identifies overlapping influences on student learning that include student characteristics, teaching characteristics and contextual characteristics, such as the institutional or departmental culture (Vermunt, 2005). Entwistle (2005) reported on the notion of *congruence* to describe "a whole range of interacting contributions" that impact on the achievement of "high-quality learning processes and outcomes" that includes congruence with students' backgrounds, knowledge and aspirations.

Therefore, mismatches between teaching and learning preferences and approaches are not the only factors to be considered in regards to possible barriers to learning. So, how does this interact with the question of matching or intentionally mismatching students' learning styles with lecturers' teaching styles? Can/should mismatches be intentionally created to simulate real work environments, where, as graduates, students will need to function effectively, in spite of circumstances beyond their control?

The organisational requirements on academic staff to concentrate on research, often at the expense of scholarly teaching, greatly reduces the likelihood that they will spend time reflecting on or researching teaching issues. Therefore, there is a critical and immediate need for the higher education sector to have discipline-based learning and teaching research recognised as legitimate research.

The preliminary comments presented here indicate that there is a wealth of information still hidden within the student focus group discussions and staff interviews data. These will be the subject of more in depth analysis, to further build synergies between teaching and learning approaches, for enhanced learning outcomes and improved retention rates.

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REFERENCES

Angelo, T. & Cross, P. 1993, *Classroom Assessment Techniques: A Handbook For College Teachers*, Jossey-Bass Publishers, San Francisco, USA.

Apter, M. J. 2001, *Motivational styles in everyday life: a guide to reversal theory*, American Psychological Association, Washington DC.

Coffield, F., Moseley, D., Hall, E. & Ecclestone, K. 2004, "Learning styles and pedagogy in post-16 learning: A systematic and critical review", Learning and Skills Research Centre, www.LSRC.ac.uk, accessed October 2008.

Engineers Australia, 2006, *The Engineering Profession: A Statistical Overview*, 4th Edition.

Entwistle, N. 2005, "Ways of Thinking and Ways of Teaching across Contrasting Subject Areas" www.ed.ac.uk/etl/docs/etlISL2005.pdf, accessed September 2008.

Felder, R. 1993, "Reaching the Second Tier: Learning and Teaching Styles in College Science Education", *Journal of College Science Teaching*, Vol. 23, No. 5, pp. 286-290.

Felder, R. 1999, "Index of Learning Styles (ILS)", www2.ncsu.edu/unity/lockers/users/f/felder/public/ILSpage.html, accessed October 2008.

Felder, R. & Silverman, L. 1988, "Learning and Teaching Styles in Engineering Education", *Engineering Education*, Vol. 78, No. 7, pp. 674-681.

Grasha, A. 1994, "A matter of style: The teacher as expert, formal authority, personal model, facilitator and delegator", *College Teaching*, Vol. 42, No. 4.

Grasha, A. 1996, *Teaching with style: A practical guide to enhancing learning by understanding teaching and learning styles*, Alliance Publishers, Pittsburgh, USA.

King, R. 2008, "Addressing the Supply and Quality of Engineering Graduates for the New Century", www.altc.edu.au/carrick/webdav/users/siteadmin/public/Grants_DBIprojec_engineeringquality_project%20report_25march08.pdf, accessed October 2008.

Mills, J., Ayre, M., Hands, D. & Carden, P. 2005, "Learning about learning styles: Can this improve engineering education?", MountainRise, http://facctr.wcu.edu/mountainrise/archive/vol2no1/html/learning_about_learning.html, accessed October 2008.

Taylor, P. 2008, "Fixing Australia's engineering skills shortage is an urgent and shared responsibility", www.engineersaustralia.org.au/news/media-statements/2008-media-statements.cfm, accessed October 2008.

Vermunt, J. D. 2005, "Relations between student learning patterns and personal and contextual factors and academic performance", *Higher Education*, Vol. 49, pp. 205-234.

WAGEEH BOLES

Wageeh Boles is currently a Professor at the School of Engineering Systems, Faculty of Built Environment and Engineering, Queensland University of Technology (QUT), Brisbane. He was an Assistant Professor at Penn State University, USA, prior to joining QUT. He held the position of Assistant Dean (Teaching and Learning), Faculty of Built Environment and Engineering, QUT, from 1999 to 2004. He has been successful in obtaining numerous competitive research and teaching development grants, and has more than 150 publications as journal and conference papers, book chapters, theses, and learning and teaching software packages. He has also published widely in the areas of biometric identification using iris and palm features, object recognition, robot vision, technology and education, work integrated learning, curriculum design, and the study and utilisation of learners' cognitive styles. Wageeh was awarded two Outstanding Teaching Assistant Medals, at the University of Pittsburgh, USA, in 1987-88. Since joining QUT, he won several university and national awards, including the Engineers Australia and Australasian Association for Engineering Education (AaeE) Award for Excellence in Teaching and Leadership in Engineering Education. In 2007, he was President of the AaeE and was awarded an Australian Learning and Teaching Council (ALTC) Associate Fellowship.

ROGER HADGRAFT

Roger Hadgraft is a civil engineer with more than 15 years involvement in improving engineering education. He has published many papers in the area, with a particular focus on problem/project-based learning (PBL) and the use of online technology to support learning in this way. He was instrumental in introducing a project-based curriculum into civil engineering at Monash University, commencing in 1998, and at RMIT in civil, chemical and environmental engineering from 2002-2006. Roger has consulted on PBL to universities both nationally and internationally. He has been a member of the Australasian Association for Engineering Education (AAEE) Executive since 2001 and was its 2008 President. Roger is the Director of the Engineering Learning Unit at the University of Melbourne, where he assists in the introduction of the new Melbourne Model in engineering, supporting new project-based learning courses and learning spaces, and improving teaching quality across the Melbourne School of Engineering. He has also been involved in issues of sustainability for the last five years. He is an ALTC Discipline Scholar for Engineering and Technology, and is also involved in several ALTC projects.

PRUE HOWARD

Dr Prue Howard is a senior lecturer and Convenor of the Future Engineering Education Directions (FEED) research and scholarship group at CQUniversity. She has a BEng (Mech), a ME in Dynamics and a Professional Doctorate in Transdiciplinary Studies. She moved to the higher education sector in 1990 after a career as a mechanical designer in industry. A love of teaching has kept her there since. Prue has received National Awards in the areas of Women in Engineering and Curriculum Innovation, as well as having received the university's Vice-Chancellor's Award for Quality Teaching and the Dean's Award for Teaching Excellence twice. Since 1994 her research has centred around engineering education, resulting in significant publications and grants. A major outcome of early grants was the evidence to introduce PBL initially as a philosophy, and then as the basis for the university's Carrick Award winning engineering programs. Since then she has been involved in research in the area of Safe Design and the transdisciplinary teaching of safe design. Research areas now include the development of identity and how this can impact on student learning.