



THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA

Final Report for Senior Fellowship Program

ENGINEERING SCIENCE AND PRACTICE: ALIGNMENT AND SYNERGIES IN CURRICULUM INNOVATION

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www.altcexchange.edu.au/engineering-theory-and-practice

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2009



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1.0 Executive summary

A major and recurring theme in the assessment of engineering education is the abiding lack of strong linkages between theory and practice. This has a long and sometimes inelegant history dating back to the genesis of formal institutional engineering education in the early 1800s. This fellowship has focused on understanding three principal areas within modern engineering education which reflect the theory-practice partnership.

First, it involves the theory-practice space in which professional engineering education occurs. Second, the novel and emerging practice forms that might have significant impact on engineering education into the 2020s are investigated. Finally, the curricular structures and processes that will help deliver the necessary outcomes for future graduate engineers through the use of these spaces are highlighted.

The fellowship program specifically addressed the theory-practice landscape, namely the wide variety of spaces and places where student engineers encounter theory and practice. It is clear that the idea of spaces and places is an enduring theme in general education as witnessed by both historic and recent commentators in the following quotes,

*We never educate directly, but indirectly by means of the environment. Whether we permit chance environments to do the work or whether we design environments for the purpose makes a great difference.*¹

*A curriculum ... has to be understood as the imaginative design of spaces where creative things can happen as students become engaged.*²

The major findings from this program are in three key areas:

- The fundamental importance of learning spaces and places in building graduate capabilities and the representation of such spaces-places in a map for use in course and curriculum considerations
- The emergence of a range of engineering themes that will continue to shape the future of engineering education
- The alignment aspects and the synergies that underpin the development of course and curricula in the engineering education sector

This program has led to a novel understanding and mapping of those spaces into the theory-practice landscape map. It captures in highly visual form the broad sweep of engineering educational spaces and places that can be used to facilitate graduate attribute development. In creating the landscape map, the affordances of such spaces are emphasized as well as other key attributes of these spaces. This provides a powerful view into the nature of existing engineering curricula as well as a design tool for building novel future curricula. It is extensible and also applicable across many disciplines.

Complementing the issue of the existing theory-practice landscape are the emerging forms of modern engineering, characterized by the ubiquitous nature of modeling, simulation and 4D visualization. Information and communication technologies combined with multiple socio-

¹ Dewey, John, 1916, *Democracy and Education – An Introduction to the Philosophy of Education*, New York, Macmillan, pg 21.

² Barnett, Ronald and Kelly Coate, 2005, *Engaging the curriculum in higher education*, Open University Press, UK (preface)



technical dimensions of modern global engineering practice have been documented and discussed in forums related to the program. These issues provide significant challenges for engineering educators in devising curricula that meet the future needs of the 'global engineer'.

The alignment strategies between engineering theory and practice that utilize available and emerging learning spaces, coupled with pedagogic considerations, are crucial in curriculum design and delivery. Active learning strategies such as project and problem based learning, project centred curriculum and peer teaching models have been documented and emphasized through this program.

Of key significance for Australian engineering education have been emerging national and international networks that have been identified, reinforced, and in some cases established through this program. The challenges that Australian engineering education faces are global in nature and shared by many jurisdictions. They often require globally based solutions.

The fellowship focus is in fact a generic problem faced by many disciplines in the higher education sector. It is clear that the nexus between theory and practice in numerous professional disciplines is of vital concern to academe, professional bodies and employers. It is also a pervasive issue in many other knowledge domains. As such, there are opportunities for cross-fertilization with other key programs being conducted through the auspices of the ALTC, Australian academic institutions and their overseas counterparts.

This fellowship has helped thread together some important educational themes across the Australian engineering community and in-part has brokered strategic links to a range of on-going activities within the Australian and international communities. Some of these linkages are across existing ALTC sponsored projects and programs, others into the UK and USA. The fellowship program has provided a substantial basis to engage more deeply with the engineering and technology communities within Australia in order to help affect vital change in the educational landscape.

The ultimate goal is that Australian engineering graduates will be the beneficiaries of educational innovation in engineering education.



2.0 Fellowship Program Objectives³

The three main goals of the program were:

1. Identifying and mapping the contemporary engineering theory-practice landscape. This will lead to a comprehensive documentation of practice forms, their attributes, the means and degree whereby they contribute to engineering graduate outcomes.
2. Researching emergent engineering practices and their potential impact on engineering education. This includes the identification of new and emerging practice trends in professional engineering organizations. It addresses the implications of emerging technologies, the effects of engineering globalization, emphases on creativity, innovation and the impact of major drivers such as climate change and sustainability.
3. Developing the alignment strategies associated with engineering curriculum renewal and innovation. This will address the key structural and functional issues that lead to curricula and courses that provide synergistic alignment of engineering science and practice for engineering education.

Action towards these goals was to be enhanced through web-based technologies that will seek to engage in as wide a manner as possible the engineering education sector – both national and international in extent.

³ See Appendix for the generic *2006 Fellowship Scheme Objectives* (pg 32)



3.0 Approach and methodology

In addressing the challenges of the program objectives it was important to proceed on a firm basis that allowed the individual goals to have cohesion and to have underlying major conceptual framework. The following approaches and methodology were adopted:

1. An historical review of the relationship between theory and practice in engineering education since the inception of formal engineering schools in the USA, UK and Europe. This sought to understand the major factors that led to significant changes over the last 200 years in engineering programs.
2. The development of a framework that captures where engineering theory and practices takes place. This would lead to a concise representation of the spaces and places influential in generating important graduate capabilities in engineering graduates.
3. The use of national seminars at major universities (Go8, ATN and non-aligned institutions) to raise debate about the interface between engineering theory and practice
4. The use of an Engineering Education Futures Forum in 2008 to provide a venue for consideration of engineering and education into the period 2015-2020. This required a wide range of stakeholders include profession organizations, industrialists, students, engineering academics, senior executives of universities, deans and associate deans.



4.0 Major activities and findings from the program

The major findings from this program are in three key areas:

- The fundamental importance of learning spaces and places in building graduate capabilities and the representation of such spaces-places in a map for use in course and curriculum considerations
- The emergence of a range of engineering themes that will continue to shape the future of engineering education
- The alignment aspects and the synergies that underpin the development of course and curricula in the engineering education sector

4.1 The theory-practice spaces and places landscape.

Consider these learning scenarios:

- As part of your professional training, imagine being in a lecture theatre for several hours. That lecture theatre might typically have physical dimensions of 10 to 20 metres in floor plan.
- Now, take yourself to a major operating site such as a minerals processing plant where you work for several months on a site learning program. That site will often be kilometers in physical size.
- For a major team presentation within your company you rehearse aspects of the content and relevant application as you travel by train to work that morning.
- Now you take on a learning challenge in a virtual reality, immersive environment at your home or in a computer laboratory. The full-scale plant has now been reduced to the physical size of your LCD screen and you can experience activities in the plant in this environment that take several minutes rather than hours or days on the actual site. Time and space have been compressed.
- Finally, your learning activity in a nano-engineering course requires you to visualize the assembly of carbon atoms into a nano-tube structure. You amplify the spatial and temporal aspects through use of a computer modeling and simulation tool that has powerful visualization capabilities.

These examples illustrate that learning and the engagement of theory and practice take place in real, virtual and cognitive spaces, each with their characteristic physical spaces and characteristic learning times. This provides a powerful framework for representing and exploiting spaces and places in learning environments.

This fellowship has advanced a conceptual framework which allows the learning spaces and places to be represented in a compact and useful way for a number of applications. This is a unique and cohesive representation of the spaces and places in which engineering learning occurs. It is shown in Figure 1.



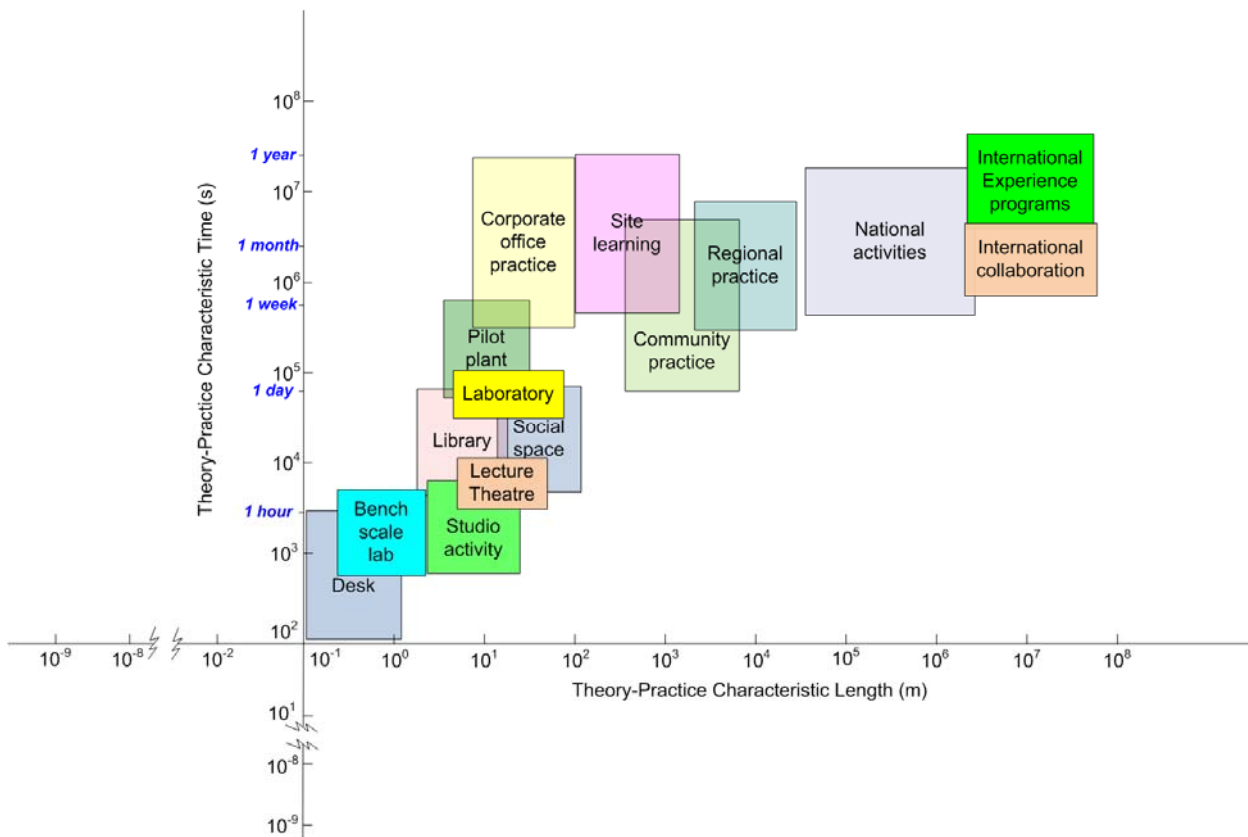


Figure 1 The engineering theory-practice landscape

Some general features extracted from such a map are:

- Small scale experimental areas are typically, but not necessarily, associated with small scale or shorter characteristic learning times compared with say, site learning. Theory and practice partner within such a space in a variety of ways.
- National or international activities at the top right of the map indicate large physical distances over which learning might take place and are typically associated with extended engagement times.
- There is a group of learning spaces in the mid-range associated with such spaces as site learning and professional office environments.
- There are “white” areas on the map that represent actual and potential virtual environments that are attenuated or amplified to the desk or studio regions.

The theory-practice map provides an interesting and useful way of classifying a range of learning spaces.

However, the landscape map has a further dimension related to a range of attributes that are co-incident with the space or place. These relate to important considerations and affordances characteristic of that space. These are seen as the third dimension in the 3D representation given in Figure 2. The key attributes at this stage of framework development relate to:

- Exemplars in the use of individual spaces
- Capabilities developed or potentially developed in the space
- Benefits gained and cost incurred in adopting a learning space
- People likely to be present in such a space and the derived affordances
- The appropriate or most effective technologies that can be attributed to these learning spaces.



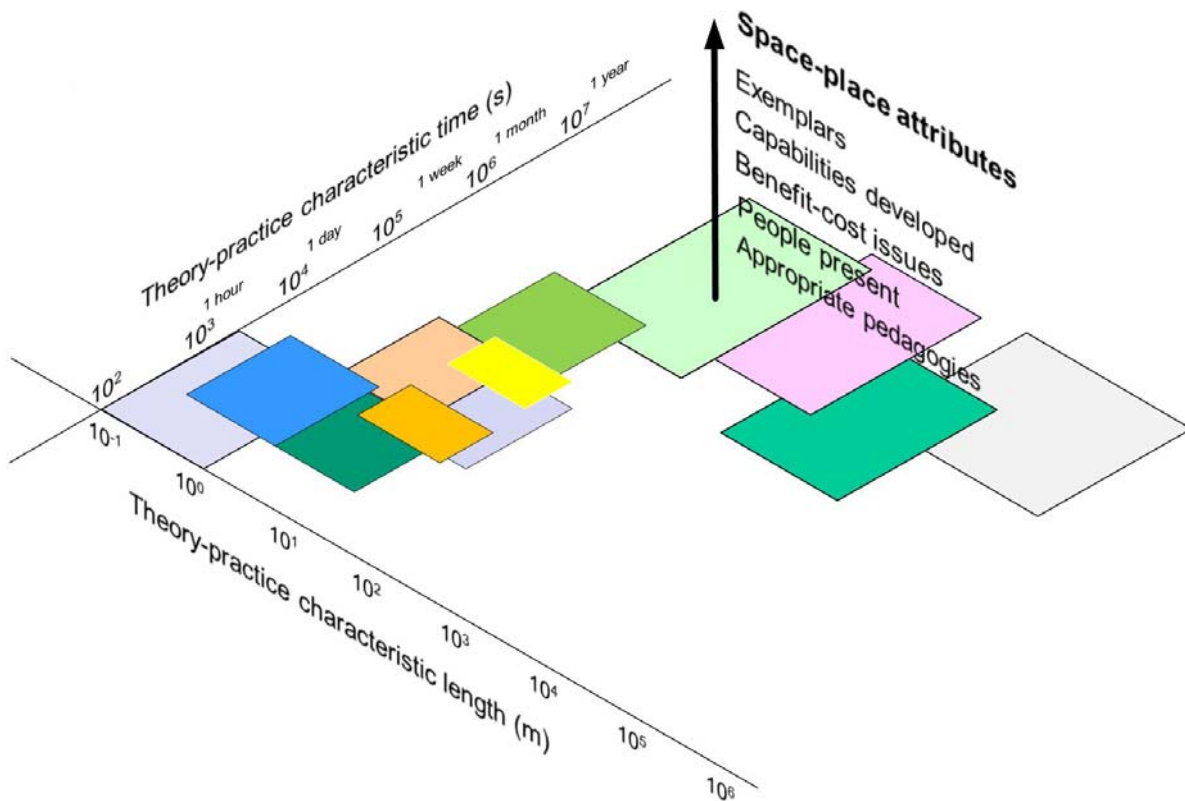


Figure 2 The space-place attributes within the theory-practice landscape

There are several ways in which the landscape map can be utilized. These include:

- Mapping current course and curricula onto the map to immediately show the space-places traversed by the curriculum design
- Assessing the character of existing curricula and exploring the possibilities of curricular change
- Using the landscape as a means of value-adding to existing curricular design methodologies
- Using the framework as an awareness tool for engineering educators in designing courses and program curricula
- Disseminating the character of learning spaces through a cohesive framework presented in graphical form readily recognizable by engineers
- Extending the framework by utilizing the inherent extensibility of the representation thus capturing insights of engineering educators and other disciplines
- Extending and adapting the representation into other discipline areas that can map discipline specific spaces onto the landscape and then exploit the representation

These details and other extensions are part of on-going activities on the ALTC Exchange.



4.2 Emerging practice and themes in engineering and their potential impact

4.2.1 Dimensions of modern engineering

Engineering in the 21st century has many existing and emerging dimensions. In Figure 3, those dimensions and their spanning end-points are illustrated.

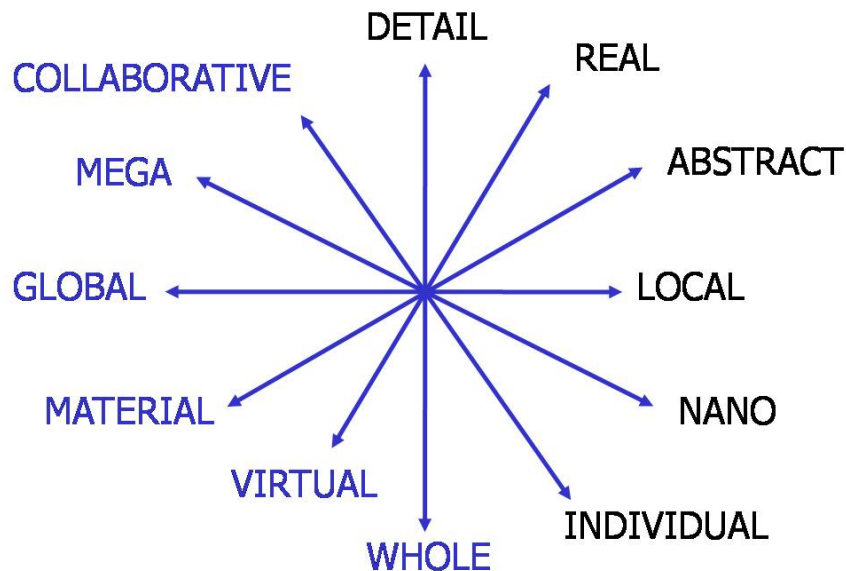


Figure 3 Dimensions of modern engineering practice

Figure 3 shows the extremities of engineering theory and practice, throwing a range of interesting challenges into the engineering education realm. The realization of these dimensions within modern engineering curricula is clearly one of immense importance and a necessary driver towards innovation in engineering education.

Engineers now:

- Consider carefully the holistic system's view of product and process design and the detailed engineering issues
- Traverse the real world of engineering applications and the virtual world of conceptual and detailed design often done in advanced computer-based environments
- Bridge the abstract world of mathematical representations of physico-chemical phenomena and the implications of that phenomena in engineering designs
- Extend from the local considerations of engineering to global aspects of the engineering enterprise set in multi-cultural contexts
- Span the time and length scales of the nano-world of molecular design to considerations of mega phenomena such as climate variability
- Experience the roles of engineer as an individual contributor to multi-disciplinary and global teams working on major projects

These modern engineering dimensions are impacting on how the higher education sector will do its business.

Other key issues are highlighted in the following two subsections.



4.2.2 Data-centric engineering

Modern engineering has been influenced greatly by the impacts of information and communication technologies (ICT) and importantly by the growth in data, information and knowledge from the basic sciences. This 'data-centric' world in which engineering planning, concepts, design and operation resides, presents many challenges to educators in how data, information and knowledge is handled, understood and applied to a range of global challenges in which engineering is and will play a vital role. The growing international efforts to promote 'life-cycle data' representations, will impact on how engineers do business in the future.⁴

A principal challenge in this area is the need to add 'wisdom' to the triplet of 'data, information and knowledge'. What can be achieved in engineering programs and what must be left to the role of continuing professional development in cultivating wisdom in engineering decision-making?

4.2.3 Model-centric engineering

Modern engineering, as practised by major consultancies, design houses and operating companies, is now driven heavily by advanced modeling, simulation and visualization tools. These are often coupled to team activities geographically separated. Figure 4 (courtesy of Hatch, <http://www.hatch.ca>)



Figure 4 Model-centric engineering practice, enhanced through modeling, simulation and visualization

There is clearly uptake of such advanced ICT tools in engineering education. However, there are significant challenges to be faced in the adoption of such practices within engineering curricula, including:

- What level of exposure is beneficial in engineering programs?
- What key skills should be considered in the use of such practices?
- What are the best pedagogies to adopt in using such practices?

⁴ ISO15926: Industrial automation systems and integration – Integration of life-cycle data for process plants

- How can deep insight and critical analysis skills be developed or enhanced through the use of such engineering design environments?
- How can creativity be fostered and enhanced through such tools?

These are but a few of the issues that require further consideration within curriculum and course development. Familiarity with the growing research literature around these themes is needed to provide informed decision making. Adoption of such environments throughout the curriculum could potentially lead to novel educational approaches for a generation of learners who are heavily screen-based.

4.3 Alignment and synergies in course and curriculum development

The last area of the fellowship activities related to understanding how alignment between discipline content and educational processes can lead to synergistic outcomes within the curriculum that impact on engineering graduates.

This issue was found to be extensive in issues and the fellowship has simply provided an outline of key ideas that require further development. Of the important “processes” and concepts revealed through the fellowship activities, the following are some key aspects that drive alignment and synergies within curriculum development.

- Pedagogy, andragogy and heutagogy: their understanding and application
- Whole-of-curriculum design philosophies
- Work integrated learning (WIL) practices and their deployment
- Industry engagement strategies for students, complementing WIL
- Engineering projects in community service (EPICS) to broaden the understanding of socio-technical aspects of engineering
- Conceive, Design, Implement and Operate (CDIO) curriculum design models that help enthuse, engage and inform students

Many of these issues are documented, referenced and discussed within the fellowship areas on the ALTC Exchange. Internal links to other sections and resources within the ALTC Exchange and links outside the Exchange provide a resource for those interested in alignment strategies and practices within engineering curricula.

4.4 Key networks developed

The key networks that have been developed or enhanced through this fellowship are represented by national linkages and international linkages. These networks have been vital in garnering support for much of the outcomes and interest in the fellowship activities. These networks have also raised the profile of the ALTC both nationally and internationally.

National network developments

These network developments include many Australian university departments and faculties in the Group of Eight (Go8) universities, the Australian Technological Network of universities (ATN) and non-aligned faculties. It also included the Business Higher Education Round Table (BHERT) and other major professional institutions such as The Institution of Chemical Engineers (IChemE) and Engineers Australia (EA). Other linkages are seen in Figure 5.



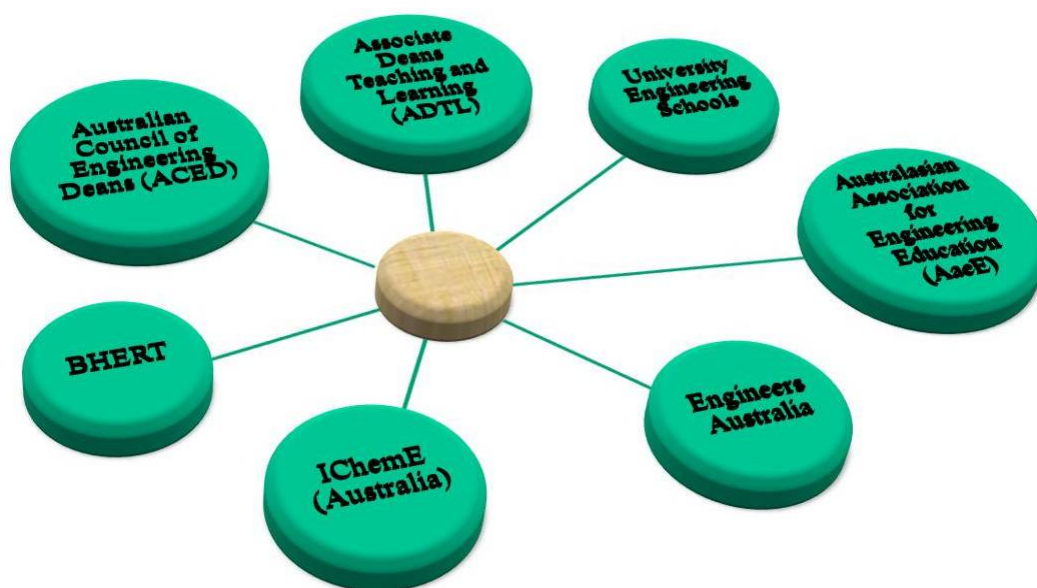


Figure 5 Major national network linkages developed through this fellowship

The linkages that have developed are important in that they have helped connect key stakeholders to a range of important engineering issues raised by the fellowship. These stakeholders include parts of the academic community, deans and associate deans across the sector, professional engineering bodies and industry representatives interested in the current state of engineering education. These linkages provide a basis for further dialogue and action.

International network developments

In a similar manner to national linkages, the international linkages are seen in Figure 6.

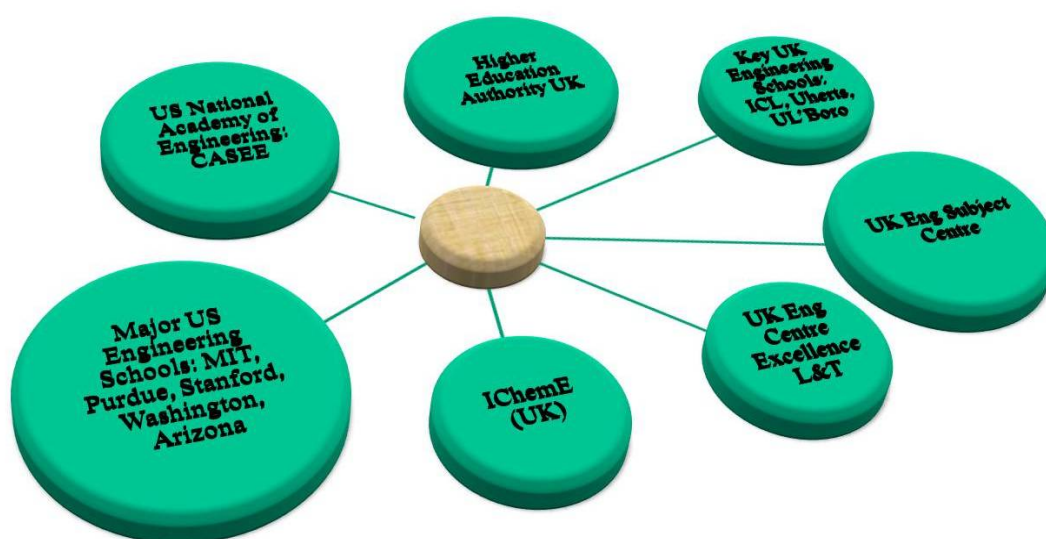


Figure 6 Major international network linkages developed through this fellowship



The international linkages are important because they have linked the fellowship activities and hence Australian issues into the global engineering scene. This is important as many issues faced within Australia are evident in other regions such as Europe and the USA.

These linkages provide a ready vehicle for potential collaboration with major players within the USA, UK and continental Europe. It also links some of the fellowship activities into key agencies in the USA and UK. These include such agencies as the US National Academy of Engineering, major engineering schools, amongst which are MIT, Purdue, Stanford, Princeton and Washington. Within the UK, key organizations such as the Higher Education Academy (HEA) and related centres such as the Engineering Subject Centre (EngSC) and the Centre for Excellence in Teaching and Learning in Engineering (EngCETL) provide important linkages for Australian academe. These organizational linkages are complemented by growing relationships some universities amongst which are Imperial College London, University of Loughborough and the University of Hertfordshire. Clearly many other players occupy the academic learning and teaching space within the USA, UK and Europe.

These existing linkages are now being exercised in various ways, and include the possibility of the Discipline Scholar initiative contributing further to the relationships.



5.0 Factors critical to program outcomes

A number of factors were critical in seeking to reach good program outcomes. These included:

1. Interaction with a collaborative program team that could help direct, facilitate and contribute to the program activities. In this fellowship an initial structure was established as seen in Figure 7.

Some comments are apposite in describing the anticipated interactions and actual outcomes. Key issues included:

- a. National and international collaborators were high profile persons in positions of senior academic management. This was important in helping facilitate the fellowship activities with key universities and also with major engineering related organizations.
 - b. The danger in having such a high profile group of collaborators and mentors is access to their time. This proved to be an issue, especially when a number of collaborators changed their positions and responsibilities. This aspect needs to be carefully considered in any fellowship program. This issue did not significantly affect the fellowship activities.
2. Engagement with the various stakeholders was crucial. In this fellowship, it was important to engage well with:
 - a. Academic staff at a range of institutions in order to raise a number of issues related to the engineering theory-practice interface
 - b. Department or school heads, deans or associate deans (teaching and learning) to gain credibility with academic institutions to help facilitate entry into the engineering education community.
 - c. Industry people, in order to obtain their voice on what they often regard as a vital issue for them.
 - d. Industry sectors such as the IT and software tool developers in order to discuss current and future trends in engineering software systems that will change and enhance professional practice. These developments will have potential impacts when considering course and curriculum reviews.
 3. A measured expectation of what can be done in the time available. This is very important as an over-expectation of what can be accomplished in a short period of the fellowship can be detrimental to the outcomes. In this fellowship, the outcomes were expected to be a base for an on-going engagement with the sector, both nationally and internationally. The following reflections are relevant:
 - a. The outcome of mapping the theory-practice landscape was successful in providing a useful framework for on-going discussions within and outside the sector. The representation in a single multi-dimensional diagram has proved extremely useful.
 - b. The challenge that was set in documenting the various attributes as seen in Figure 2 is a partially completed activity which will rely on further engagement from the engineering community. Some useful documentation has been achieved within the ALTC Exchange. More



needs to be done and this may well happen as part of on-going Discipline Scholar initiatives within 2009-2010.

- c. The recognition of new engineering practice concepts has commenced, with some of the key developments captured within the fellowship activities. The full implication of these emerging engineering developments and their possible impacts on curricula is still uncertain and requires substantial discussion within the academic community in conjunction with professional accreditation agencies and industry representatives.
4. Ability to juggle on-going responsibilities at the home institution with those attached to the fellowship. For most fellows this is problematic, especially when some have major Australian Research Council grants and some might also have other ALTC grants. Other issues relate to teaching duties at the home institution and these must be relieved for any effective conduct of the fellowship.

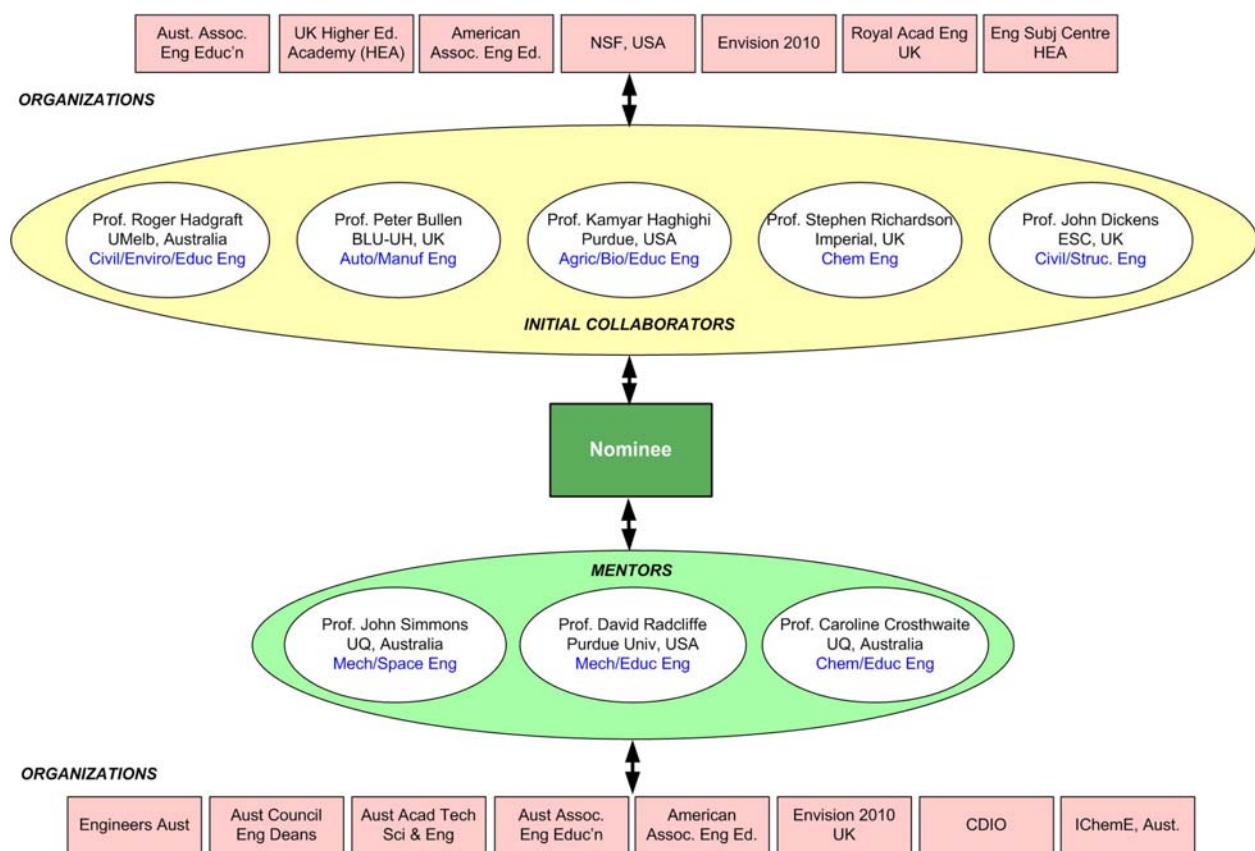


Figure 7 Collaborative and mentoring arrangements for fellowship

6.0 Transferability of approaches and outcomes

The fellowship focus is in fact a generic problem faced by many disciplines in the higher education sector. It is clear that the nexus between theory and practice in numerous professional disciplines is of vital concern. It is also a pervasive issue in many other knowledge fields. As such there are opportunities for cross-fertilization.

This fellowship has benefitted from the insights of colleagues who have come from other quite different disciplines such as the health professions.

Specifically, the transferability of the theory-practice space map could be helpful in considering the nature of the learning spaces for other disciplines. Within engineering it can be used to immediately see the nature of an individual course or curriculum as the regions in which a learner occupies throughout the degree program are evident through the mapping of the learning journey onto the map. For instance, Figure 8 shows what spaces might be occupied by an engineering degree program that has a clear emphasis on global engineering concepts.

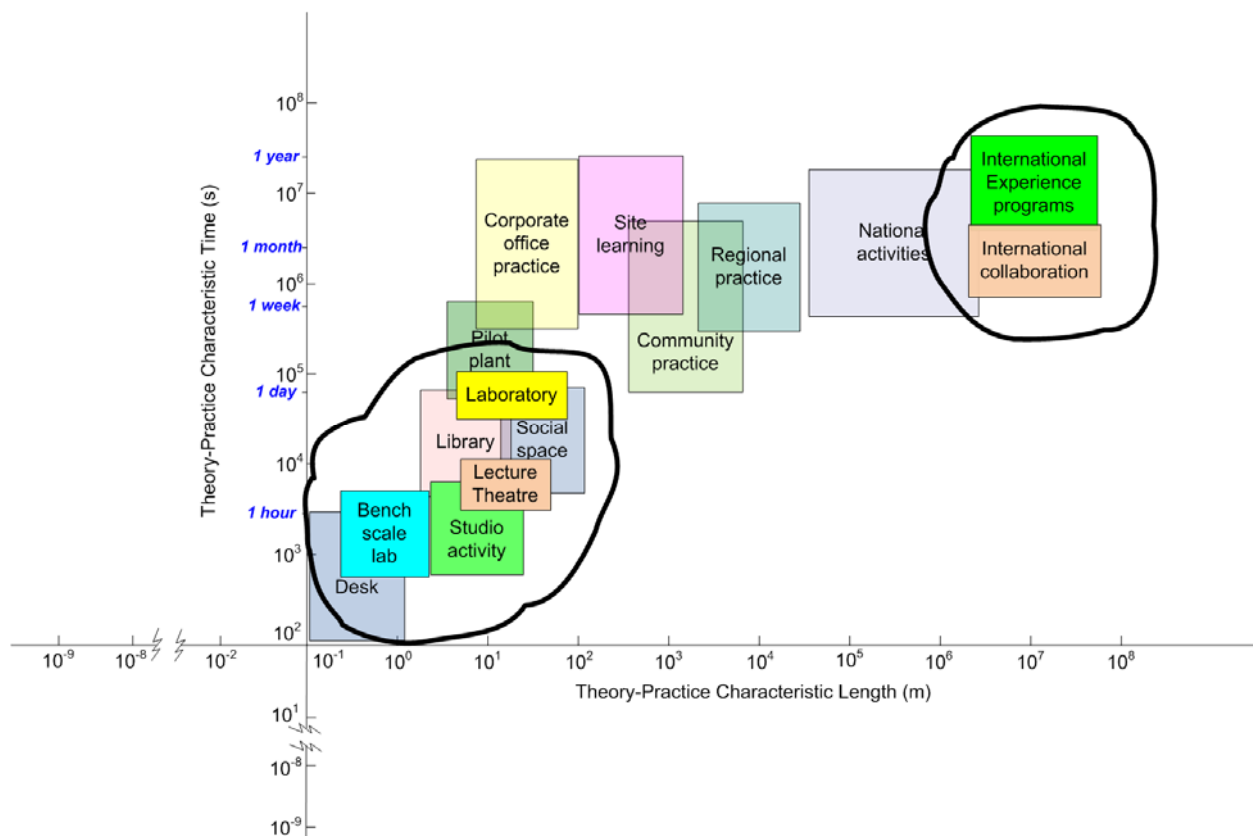


Figure 8 Possible characteristics of an international engineering curriculum

Other applications of the framework have been mentioned in section 4.1. An important outcome of the framework development is the growth of diversity between program offerings across institutions and the ability to see the nature of the programs in a comprehensible “snap-shot” as seen in Figure 8. More detailed mapping of time spent in each learning space and the frequency of engagement in those spaces gives deep insight into the nature of engineering curricula.

The comments made in the engineering context have direct application to many other discipline areas and as such as eminently transferable.

7.0 Dissemination of program outcomes

Program outcomes have been and continue to be disseminated across the sector via a number of mechanisms. The various mechanisms have led to a very wide exposure of the activities of the Australian Learning and Teaching Council (ALTC). The fellowship activities do naturally lead to the fellow becoming an unofficial ambassador for the Council wherever that might be. As such the existence and the work of the Council has been widely disseminated.

The following outlines some of the dissemination that has already occurred. Yet, there is much to be achieved in further engaging with engineering communities within Australia and elsewhere.

1. National and international seminars and plenary lectures

a. National presentations and plenary lectures

During the fellowship there have been a substantial number of invitations to present fellowship details at many Australian engineering universities. This has included universities and institutions in all Australian states. A full list of the presentations given in relation to the fellowship program is available in the Appendix under “Summary of invited presentations and addresses”.

b. International presentations

Again, these presentations have often been facilitated by collaborators. Plenary presentations have been made at a wide range of conferences as an ALTC fellow and invitations to USA, UK, Continental Europe, Israel and Oman have been as a representative of ALTC. International seminars and plenary lectures appear in the Appendix under “Summary of invited presentations and addresses”.

2. The ALTC Exchange

The ALTC Exchange has been heavily used to report on activities carried out during the fellowship. A large amount of material related to the underlying issues in addressing the engineering theory-practice nexus is available as are other materials which have received debate and comment.

The major program link on the ALTC Exchange is at:

<http://www.altcexchange.edu.au/engineering-theory-and-practice>

There are significant challenges in getting academic colleagues to engage with the ALTC Exchange. This requires other mechanisms that help point to existing resources or to forums that are running online. The fellow is cognizant of the fact that much more needs to be done over the coming year to continue to build interest in commenting, generating repositories and further developing concepts through Wikis and ALTC Exchange books.



3. Engineering Education Futures Forum 2008

The Engineering Education Futures Forum held to address the future of engineering and the necessary capabilities was an important meeting of a number of stakeholders, including undergraduate students, industrialists, education innovators, deans and associate deans, professional engineering associations, and also senior university administrators.

Entry point for the forum is at:

<http://www.altcexchange.edu.au/engineering-education-futures-forum-2008>

Major synchronized resources (audio, video and slides) are available at:

<http://www.altcexchange.edu.au/engineering-education-futures-forum-2008-2-outcomes-and-activities>

4. Future activities in dissemination

A number of future activities have been discussed with the Australasian Association for Engineering Education (AaeE) to help engage engineering academics across the sector. Several activities will occur in 2009. These involve the establishment of an e-newsletter bringing the latest engineering education developments to the sector. This will be a brief HTML document, with easily clickable references to take academics into parts of the ALTC Exchange or other key resource sites. As well, to better understand the constituency, a significant engineering education demographics survey will be conducted, whose results will help inform future ways of engaging and assisting engineering academics.

There are vital opportunities within the Discipline Scholar initiative of the ALTC to disseminate further the ideas in this program over the 2009-2010 year.



8.0 Strategic links to ALTC sponsored activities

A number of strategic links were established throughout the program. These include:

1. ACED Discipline Based Initiative activity, led by Professor Archie Johnstone and Emeritus Professor Robin King
2. ALTC competitive grant on CDIO approaches to curriculum, led by Dr Carl Reidsema at UNSW
3. ALTC competitive grant on VR Immersive learning systems in process engineering that involved partners from University of Queensland, University of Melbourne, Curtin University, University of Sydney and Monash University.



9.0 Recommendations and the future

The following recommendations flowing from the fellowship are made:

- A deeper development of the theory-practice landscape map, in order to better document its significance and to investigate its deployment into the curriculum development processes within engineering schools.
- An on-going development of resources relevant to the foci of the fellowship. This can occur through specific interest groups within and outside the Exchange. A number have formed around some of the key fellowship issues, others around ALTC projects.
- The development and deployment of a focused news service alerting Australian engineering academics of developments and important news in engineering education fields. This could mirror something like the American Society for Engineering Education (ASEE) "First Bell" or the email news from the UK Higher Education Academy's Engineering Subject Centre.
- Building stronger collaborative links to the UK HEA and also the US NAE and NSF, to potentially address engineering education issues that transcend national boundaries.
- Use of the Discipline Scholar in Engineering & Technology initiative to continue to disseminate and challenge engineering academics "on the fringes" to engage in educational change activities.



10.0 Acknowledgements

I would readily acknowledge the following people and organizations that have helped in many aspects of this program to make it happen:

- To my wife, Lucille and my 3 sons for their support and love during my often many absences in the last 18 months. Thanks for enabling this work to happen!
- To The University of Queensland senior management for their support and facilitation by way of changed responsibilities to permit this program to be pursued.
- To my departmental colleagues at Chemical Engineering for providing an inspiring, creative and entrepreneurial environment to 'push the boundaries' of engineering education. You truly have been a unique group of colleagues who always encouraged and valued excellence in research, teaching and learning.
- Particularly to former colleagues Prof Peter Lee and Dr Bob Newell for many fruitful years of collaboration in systems research and educational innovation. I learned so much from those interactions.
- To the Carrick Institute, now ALTC, for their financial and other support that made this fellowship year possible. It has truly been appreciated.
- To my many friends and colleagues around the world in the USA, UK and Europe who provided hospitality, opened up their institutions to me and introduced me to a fantastic group of dedicated educational professionals. "Excellence through passion" is certainly evident in so many places.
- To my initial mentoring and collaboration team who made possible entry into some of the impressive activities in engineering education, both national and international.
- To my fellow Fellows: 'thank you' for the encouragement and inspiration through this journey.

And finally a personal reflection:

"... no os conforméis a este siglo, sino que os transforméis por la renovación de la mente, para que sepáis discernir cuál es la voluntad de Dios, buena, grata y perfecta" (Rom 12:2)



APPENDICES

Summary of program activities

August 2007:

- Background research on the Theory-Practice nexus in engineering with special emphasis on curriculum design and innovative pedagogy
- Further formulation of the learning spaces framework for theory-practice development
- Meeting with Gordon Howell on Learning Spaces as part of another ALTC grant directed by David Radcliffe and colleagues.
- Interviews with UQ academic staff on their perspectives on current effectiveness of engaging students in the engineering theory-practice learning environment
- Continued direction on a Carrick Competitive Grant on “Development, Deployment and Educational Assessment of an Advanced Immersive Learning Environment for Process Engineering Design and Operations”.
- Conversations with Mr Leigh Paskin, Associate in Hatch Engineering on Engineering Practice issues from an industrial perspective.
- Presentation and discussions with University of Melbourne engineering staff and also RMIT engineering staff on fellowship focus. Title of presentation: “Engineering Science and Practice: Alignment and Synergies in Curriculum Innovation”.

September 2007:

- Extended background research on historical issues surrounding theory-practice debate in engineering education across national boundaries (UK, France, Germany, USA)
- Key meeting with Professor James Trevelyan (UWA) regarding his work on professional engineering practice and the implications on curriculum innovation
- European Conference on Chemical Engineering (ECCE6), Copenhagen. Keynote lecture in honour of Professor John Villadsen of The Technical University of Denmark. Title: “Powders, Particles and Processes: Multiscale Approaches for Improved Performance”.
- ECCE6 presentation on “Changing a Culture: A Project Centred Curriculum for Chemical Engineering Education”. Other ECCE6 presentations on Virtual Reality Systems in Engineering Education.
- Invited plenary lecture at the Centenary Forum on Sustainability at Imperial College London, celebrating 100 years since foundation. Title of presentation: “As it was in the beginning? - Barriers and Opportunities for Change in Engineering Education”.
- Plenary address at the Australasian Chemical Engineering Conference (CHEMECA 2007) entitled: “Barbarians at the Gate: Curricular Challenges in Chemical Engineering Education”.

October 2007:

- Initial planning for a major forum in 2008 to address Engineering Education Futures focussing on the integration of engineering theory and practice
- Meeting with Professor Wageeh Boles from QUT regarding fellowship activities and potential collaboration
- Visit to Sydney:
 - Meeting with UTS Engineering staff (Profs Archie Johnston, David Lowe and Robin King)



- o Meeting with University of Sydney engineering staff: Professor Greg Hancock and David Airey regarding fellowship activities. Also met with Dr John Kavanagh and colleagues in Chemical Engineering to discuss progress on the Carrick Grant for VR-Immersive Systems development.
- o Meeting with Carolyn Webb at Carrick Institute offices in Sydney for discussions on the current status of the Carrick Exchange and development ideas
- o Meeting with UNSW staff: Professor David Clements, Graham Bushnell and Carol Russell (L&T Fellow) and Prof Rob Burford (Chemical Engineering) regarding fellowship activities and VR systems
- Planning morning on Engineering Education Futures Forum 2008 (EEFF08) with Ms Lizzie Brown (nee Webb), Education Director of Engineers Without Borders (EWB)

November 2007:

- Further planning for the 2008 Engineering Education Futures Forum especially locking in major speakers and initial advertising for the forum.
- Visit to Adelaide universities:
 - o Meeting with University of Adelaide engineering staff: Professor Peter Dowd and Dr Mark Jaksa.
 - o Invited school presentation: "Engineering Science and Practice: Alignment and Synergies in Curriculum Innovation"
 - o Visit to UniSA School of Engineering including staff: Prof Brenton Dansie, Prof Andrew Parfitt, Prof Andrew Dowling, Prof Andrew Nafalski, Mr Tim Fisher, Dr Diana Quinn and Dr Peter Hamilton. Invited presentation "Engineering Science and Practice: Alignment and Synergies in Curriculum Innovation"
- Visit to Murdoch University, Perth, meeting with senior engineering staff: Prof Parisa Bahri, Prof Yianni Attikiouzel and support staff in T&L including Dr Christine Creagh (Laboratory Manager) and Dr Greg Crebbin. Invited presentation to engineering school executive: "Engineering Science and Practice: Alignment and Synergies in Curriculum Innovation"
- Visit to Curtin University of Technology, Perth: Visiting Prof Tony Lucy (Dean) and Prof Mario Zadnik, Dr Euan Lindsay, Prof Moses Tade, Drs Nicoleta Balliu, Gordon Ingram and other academics. Invited presentations on "Engineering Science and Practice: Alignment and Synergies in Curriculum Innovation" and "Pedagogic Principles for an Immersive Learning Environment for Process Engineering". Links with BP Kwinana: Jody McDiarmid, Ken Chan and Mike Hubbard.
- Visit to UWA School of Engineering speaking with senior academics and Dean T&L. This included people such as Dr Ruza Ostrogonac (Mechanical Engineering), Ms Sabbia Tilli (Mechanical Engineering), Dr Nathan Scott and Prof James Trevelyan. Also met with Prof Carolyn Oldham and Dr Angus Tavner as Dean and Associate Dean of Engineering. Visited the new Chemical Engineering program personnel including Assoc Prof Hui Tong Chua and Dr Yee-Kwong Leong. Invited presentation: "Process and Content: In Pursuit of Graduate Attributes" and "Engineering Science and Practice: Alignment and Synergies in Curriculum Innovation"
- Invited presentation at University of Queensland's Teaching and Learning Week Celebrations. Title: "A Kiss is Still a Kiss: Putting Theory and Practice Together".
- Meeting with Professor Richard Johnstone, ALTC Director on Carrick Exchange issues, and HEA, NSF connections
- Visit to University of Newcastle, visiting with Prof John Carter, Prof William Sher, Graham Brewer, Prof Behdad Moghtaderi. Invited presentation entitled: "Engineering Science and Practice: Alignment and Synergies in Curriculum Innovation"
- Invited presentation to the Annual Australasian Clinical Anatomists Conference entitled: "Belgian Chocolates, Silky Hair and Opal Gasoline: The Importance of Enabling Sciences in Engineering".



December 2007:

- Guest speaker at the Institution of Chemical Engineers Education Forum with presentation entitled: "Chemical Engineering Education – Past, Present and Future Curricula".
- Visit to Oman and the University of Sohar as UQ representative on a QA review of engineering programs. Focus on developing engagements with local industrial complex companies and companies in the manufacturing sector. Advice on developing innovative curricula in engineering education.
- Attendance at the Australian Council of Engineering Deans (ACED) meeting to discuss issues from the Discipline Based Initiative (DBI).
- Invited opening plenary at the Australasian Association for Engineering Education Conference in Melbourne. Presentation entitled: "Engineering Theory and Practice: Can we ever get it right?" Also, technical paper and oral presentation on VR systems entitled: "Pedagogic principles for an Immersive Learning Environment for Process Engineering"
- Meeting with Prof Peter Gostomski, head of chemical engineering at the University of Canterbury, New Zealand, exploring possibilities of future collaboration on development of dairy focussed VR systems.
- Study tour travel to the UK:
 - o Visit to the Blended Learning Unit at the University of Hertfordshire visiting Prof Peter Bullen, Mark Russell and Amanda Jefferies and other engineering staff members. Particular interests in the theory-practice interface and application of VR/Immersive systems to teaching practice with Dr William Tiu.
 - o Visit to Imperial College London and meetings with Prof David Nethercot (Civil Engineering), Chair of T&L plus Dr Ruth Graham, director of Imperial College's Envision2010 project for engineering education innovation.
- UK vacation period for 2 weeks over Christmas and New Year period.

January 2008:

- Continuing study tour activities in the UK:
 - o Visit to the Higher Education Academy, York and discussions with Sean Mackney (Deputy Chief Executive) on collaborative possibilities, Eddie Gulc (Engineering liaison), Jean Downey (Programme Manager) and Sal Cooke (JISC Head of TechDis, Disabilities activities).
 - o 1 week at the Engineering Subject Centre (EngSC) of the HEA at the University of Loughborough hosted by Prof John Dickens. Key people informing the discussions were:
 - Mr Rob Pearce, Information Systems (generating internet collaboration)
 - Dr Caroline Lowery (Learning Technology)
 - Jenny Logan (Online Learning Co-ordinator)
 - Dr Simon Steiner (Academic Advisor, liaison work across UK departments)
 - Dr Jane Pritchard (Learning and Teaching Advisor)
 - o Visit to the Engineering Centre for Excellence in Teaching and Learning (EngCETL), discussing a range of theory-practice issues with:
 - Dr Sarah Bamforth (Pedagogic Research Associate)
 - Steve Loddington (web peer assistance)
 - Richard Newman (industry liaison)
 - Kirsty Carter (academic co-ordination)



- o Visit to Mechanical and Manufacturing Engineering at Loughborough and discussions with Prof Robert Parkin (Head of School, Professor of Mechatronics); Dr Peter Willmot (Director of UG Studies)
- o Visit to Chemical Engineering: Prof Richard Holdich (Head of Department), Dr Zoltan Nagy (control, remote and virtual laboratories)
- o Attended a EngSC sponsored workshop on 'Student Centred Learning in Small Groups' with around 30 academics drawn from all over the UK. Focus on Enquiry Based Learning (EBL). Met with Ivan Moore, Director of the Centre for Promoting Learner Autonomy (CPLA) at Sheffield Hallam University in Sheffield.
- Continuing study tour to Denmark and Sweden:
 - o Visit to The Technical University of Denmark, especially Chemical Engineering
 - o Visit to the School of Engineering, Lund University in southern Sweden. Met with staff at the Pedagogic Academy within the Faculty of Engineering. Key discussions around pedagogy, rewards and the theory-practice interface in engineering education. Key people in discussion were:
 - Prof Torgny Roxå, academic developer and concepts surrounding rewards systems in terms of changing behaviours in academics. Role of attitudes to teaching inventory (ATI) developed by Trigwell and Prosser. Also discussions on academic tribes and territories (Becher and Trawler) in terms of promoting change. Discussed issues surrounding reflection (Reflective Practitioner by Donald Schoen)
 - Dr Anders Ahlberg
 - Prof Thomas Olsson
 - Dean of Engineering
- Continuing study tour to the USA:
 - o Visit to the Massachusetts Institute of Technology (MIT), Boston. Several days spent with key people in the area of Aero/Astro Engineering as well as Mechanical Engineering. Focus on the CDIO (Conceive, Design, Implement and Operate) activities within MIT. Inspection of the new student facilities that facilitate the conception, design, implementation and operation of aero/astro student projects. Key people in the discussions included:
 - Prof Edward Crawley (CDIO, Bernie Gordon Engineering Leadership Program)
 - Doris Brodeur (Educational development and CDIO assessment)
 - Prof Paul Lagacé (Colossal failures teaching and pedagogy)
 - Prof Woodie Flowers (FIRST Program for engaging secondary students, practical aspects of engineering and student assessment)
 - Dr Janet Rankin (Associate Director for Teaching Initiatives, educationalist interested in academic demographics)
 - Dr Bill Litant (Communications Director for Aero/Astro Engineering)
 - Dr Elizabeth Cooper (Associate Director of the Cambridge-MIT Institute)
 - o Visit to Mechanical Engineering and discussions with Prof Warren Seering on graduate activities and important attributes post-graduation. Views on 2-phase education: intense university phase and then continuing education phase up to about age 30.
 - o Met with Dr Phil Long, directing the educational innovation practices at MIT.

February 2008:

- Visit to Purdue University, West Lafayette, Indiana. Embedded in to the Department of Engineering Education investigating key issues currently being researched by staff members
- Invitation to the University of Arizona in Tucson, AZ
- Visit to Mechanical Engineering Department at Stanford University including the D.School



- Invited speaker at the Business Higher Education Round Table meeting in Melbourne (Theme: Global Dimensions of Engineering)
- EEFF2008 preparation of program and visit to Novotel Twin Waters
- Visit to School of Engineering, James Cook University, Townsville (Theme: Theory and Practice in Engineering Education)

March 2008:

- Visit to Sohar University, Oman on behalf of the University of Queensland with regard to building strategic links with local industrial complex and manufacturing companies. Visit to the Research Ministry of the Oman Government in Muscat, Oman
- Final planning and preparations for the Engineering Education Futures Forum 2008, to be held in Queensland.
- Co-ordinating and leading the Engineering Education Futures Forum 2008 at Novotel Twin Waters Resort on the Sunshine Coast, Queensland

April 2008:

- Invited visit to the University of Tasmania, School of Engineering in Hobart (Theme: Engineering Curriculum development that merges theory and practice)
- Development of the EEFF2008 outcomes and initial dissemination to ALTC Exchange website
- Linking the EEFF2008 MediaSite presentation capture into the ALTC Exchange under the group "Engineering Theory and Practice"

May 2008:

- Further background work on outcomes from EEFF2008
- Preparation of a series of invited presentations at seminars and conferences in Israel, France and Hungary
- Visit to the Hungarian Academy of Sciences in Budapest as part of an ARC collaborative research project
- Invitation to the Israel Institute of Technology (Technion) in Haifa, Israel to present several seminars on the areas of Engineering Education and curriculum innovation.
- Invited plenary presentation at ESCAPE18.

June 2008:

- Attendance at the European Symposium on Computer Aided Process Engineering in Lyon, France. Invited plenary on theme of Curriculum innovation in CAPE activities. Presentation of other topics including development of VR process engineering systems and also Advanced Diagnosis Systems for Abnormal Condition Management in large scale operations.
- Award of the "best conference paper" for the VR educational work (Funded by ALTC through a Competitive Grant Scheme)
- Invited attendance at the Technical University of Denmark, CAPEC research institute in Lyngby Denmark as an external academic member.
- Visit to the Keller Center for Engineering Education at Princeton University, USA with discussions with staff on issues of key courses across liberal arts and engineering.



- Invited presentation at the international Blended Learning Conference held simultaneously in the UK, Calgary and Brisbane. Presented a plenary lecture entitled “In the Mix”.
- Start of collaboration with Hatch Engineering through a series of sessions with senior Hatch personnel in their Brisbane offices facilitated through Mr Geoff Ensor and Mr Michael Barltrop.

July 2008:

- Invited plenary speaker at the UK Engineering Education Conference 2008 in Loughborough University. Theme of the presentation: “Engineering Education and the Spatial Imperatives”.
- Visit to research group at the Department of Engineering Science, Oxford University. Discussions on intelligent systems development in the area of policy and process systems
- Visit to the Blended Learning Unit at the University of Hertfordshire for collaborative purposes in BL and on-going work surrounding the outcomes of the Engineering Education Futures Forum in March 2008.
- Further visits with Hatch Engineering in Queensland to explore mechanisms for university-industry engagement
- Starting development of a national survey instrument to gain understanding of engineering demographics in the academic community. Development within Survey Monkey.

August 2008:

- UQ focussed work related to Diversity and Structural Adjustment in Engineering Education with reference to diversity in engineering curricula to provide options for work-integrated-learning, service in community and overseas NGOs, embedding into national and international research groups and the like.
- Work on ARC Linkage grant with BP and BlueScope Steel
- On-going work with VR development team, and preparation of submissions to major awards in the UK with the Institution of Chemical Engineers and The Australian Business and Higher Education Round Table innovation awards.

September 2008:

- Attendance at the ALTC Fellows Forum in Sydney with reflections on carrying out activities within the fellowship
- Visit to Sydney University to Prof Peter Goodyear regarding issues of learning spaces and affordances of those spaces. Potential on-going collaboration on issues of learning spaces and curriculum development.
- Mid-semester break with family
- Further Hatch Engineering development activities and presentation to senior managers at Hatch on collaboration possibilities
- Engagement with Bentley Systems (USA) on the potential of advanced engineering IT systems deployment to enhance visualization and life cycle concepts in engineering education
- Visit by senior staff from Sohar University in Oman to discuss both research and also engineering curriculum development



October 2008:

- Development of survey instrument for assessing “Academic Demographics within Engineering Schools” as part of on-going fellowship activities into the first half of 2009
- Major visit to BlueScope Steel Port Kembla by UQ research team and Hungarian partners as part of the ARC Linkage project on Advanced Diagnostic Systems
- Invited visit to the University of South Australia to discuss engineering curriculum developments and also give the occasional speech at the UniSA Celebrations for Excellence in Teaching and Learning. Theme was: “Excellence through Passion”

November 2008:

- Refinement of academic demographics survey instrument
- Assembling materials related to the engineering theory-practice interface
- Preparation for Australasian Association for Engineering Education Conference in December 2008
- Further development of the theory-practice space describing engineering curricula
- Arrangements for a 2009 visit by Dr Norman Fortenberry, Director of the Center for Advancement of Scholarship in Engineering Education (CASEE) within the National Academy of Engineering (NAE), Washington, USA.

December 2008:

- Attendance at the Australasian Association of Engineering Education conference in Yeppoon, Queensland.
- Attendance at the Associate Deans Teaching and Learning (ADTL) discussion day on key items for engineering education into 2009 and beyond



Summary of invited presentations and addresses

August 2007:

- University of Melbourne and RMIT (Theme: Engineering Education)

September 2007:

- European Conference on Chemical Engineering (ECCE6), Copenhagen: Plenary + 2 technical presentations (Themes: Particle Systems; Engineering Curricula; Virtual Reality Systems)
- Imperial College Centenary Forum, London, UK: Plenary (Theme: Engineering education change management)
- Australasian Chemical Engineering Conference (Chemeca 2007), Melbourne: Education plenary + 2 technical presentations (Themes: Chemical Engineering Education; Advanced Process Diagnosis; Virtual Systems)

November 2007:

- University of Adelaide, School of Engineering (Theme: Engineering Education)
- University of South Australia, School of Engineering (Theme: Engineering Education)
- Murdoch University, Perth, School of Engineering (Theme: Engineering Education)
- Curtin University of Technology, Perth, Faculty of Engineering and Computer Science (Themes: Engineering Education, Virtual Systems development and use)
- University of Western Australia, Faculty of Engineering (Theme: Engineering Education)
- University of Queensland Teaching & Learning Week (Theme: Theory and Practice in Education)
- University of Newcastle, NSW (Theme: Engineering Education)
- Australasian Clinical Anatomists Conference: (Theme: Importance of basic sciences in engineering disciplines)

December 2007:

- Australasian Association for Engineering Education, Melbourne: Plenary presentation + 1 technical presentation (Themes: Engineering Theory and Practice – Can we ever get it right?; Virtual Reality in Engineering T&L)
- Institution of Chemical Engineers National Education Forum ((Theme: Chemical Engineering Education: Past, Present and Future Curricula)

January 2008:

- UK Engineering Subject Centre and Engineering Centre for Excellence in Teaching & Learning (Theme: Engineering Education and Curriculum Development)
- Lund University, Sweden (Informal presentation on Engineering Education)



February 2008:

- Business Higher Education Round Table (BHERT): (Theme: Global Dimensions of Engineering)
- James Cook University, Townsville: (Theme: Theory and Practice in Engineering Education)

March 2008:

- Engineering Education Futures Forum 2008 (EEFF2008), chairing sessions related to the major Fellowship Forum.

April 2008:

- University of Tasmania, School of Engineering in Hobart (Theme: Engineering Curriculum development that merges theory and practice)

May 2008:

- Israel Institute of Technology (Technion) in Haifa, Israel to present two seminars on the areas of Engineering Education and curriculum innovation.
- Invited plenary presentation at the European Symposium on Computer Aided Process Engineering (ESCAPE18) on Chemical Engineering curriculum innovations.

June 2008:

- Blended Learning Conference (UK, Canada and Australia). Presented a plenary lecture entitled "In the Mix".

July 2008:

- UK Engineering Education Conference EE2008 at Loughborough University. Plenary Theme: "Engineering Education and the Spatial Imperatives"

October 2008:

- UniSA Celebrations for Excellence in Teaching and Learning. Occasion address theme: "Excellence through Passion".



2006 Fellowship Scheme Objectives⁵

The original stated aim of the Carrick Fellowship Scheme is to promote and support excellence in learning and teaching in higher education by supporting individuals who have the educational expertise and leadership skills to:

- devise and undertake a significant program of activities that will advance learning and teaching in Australian higher education;
- identify educational issues across the higher education system and to facilitate approaches to address these issues;
- stimulate strategic change in higher education institutions;
- raise the profile of learning and teaching in higher education and the prestige associated with the pursuit of excellence in teaching;
- establish and build on national and international partnerships in learning and teaching in higher education; and
- foster national and international collaboration and collegial networking for sharing research, innovation and good practice in learning and teaching.

Senior Fellowship activities and outcomes (2006 call for submissions)

The following outline of some expected and possible activities and outcomes for Carrick Senior Fellowships. The Carrick Institute welcomes innovative and creative proposals that will fulfill the objectives of the Fellowship Scheme.

Establish a collaborative team of respected scholars and educators (expected)

Senior Fellows would be expected to establish a collaborative team of internationally recognised scholars. Some team members may be overseas scholars. The collaborative team should support the nominated fellowship activities.

Nominees should propose the intended members of the collaborative team when the fellowship nomination is submitted. The international standing of team members, the relevance of their backgrounds to the proposed fellowship activities and their availability and willingness to contribute to the program should be demonstrated in the nomination.

Devise and conduct fellowship activities while based at their home institutions or with a group of institutions (expected)

As appropriate to their proposed fellowship activities, Senior Fellows may:

- conduct research and development for their nominated fellowship activities;
- disseminate preliminary findings of the activities through presentations and publications;
- begin embedding the outcomes of their activities in the institution(s);
- be advocates for excellence in learning and teaching in the institution(s);
- forge links between the institution(s) and the Carrick Institute; and
- promote learning and teaching in higher education at the national level.

The scheduling of the period at the home institution within the fellowship year is at the discretion of the Carrick Senior Fellow, in consultation with their home institution and the Carrick Institute. During this period, Senior Fellows may make several short visits to the Carrick Institute.

Undertake an overseas study program of up to three months

Carrick Senior Fellows may:

- visit overseas members of the collaborative team to examine learning and teaching issues from a cross-institutional and cross-national perspective;
- investigate international perspectives and possibilities that relate to their fellowship activities;

⁵ <http://www.altc.edu.au/carrick/go/home/fellowships/pid/72>



- identify the conditions and approaches that contribute to internationally recognised good practice; and
- interact with, establish and consolidate international scholarly networks that will enhance the dissemination of the outcomes of their fellowship.

Undertake a three-month residency at the Carrick Institute

Undertake a residency of up to 3 months at the Carrick Institute. Senior Fellows would be expected to play a key role in the intellectual life of the Carrick Institute. The scheduling for a residency is a matter of negotiation between each Carrick Senior Fellow and the Carrick Institute. During this period, Senior Fellows may conduct their nominated fellowship activities and undertake presentations and seminars as appropriate.

Disseminate fellowship activities and outcomes (expected)

The effective dissemination and uptake of fellowship outcomes is an important goal of the Fellowship Scheme. The Carrick Institute Seminar Series will contribute to dissemination outcomes. Senior Fellows would be expected to develop a number of the Engaged strategies outlined in the Carrick Dissemination Framework (see website) as appropriate to their fellowship activities. Strategies may also include:

- the creation of a website within the Carrick website. The website may be a mechanism for the dissemination of fellowship outcomes and could be used to host interactive online seminars that include discussion opportunities with members of the international collaborative team: and
- the production of other resources as appropriate for distribution to universities, professional associations and other bodies as appropriate.
- Publications and reports

To maximise awareness and the influence of their activities, Senior Fellows may:

- identify and engage with institutions, discipline groups, employer representatives, government bodies, media and community groups that are strategic to the advancement of the fellowship;
- create opportunities to promote the fellowship activities and to explain the goals and outcomes; and
- present publicly on the fellowship activities.

