Research-Teaching Linkages: enhancing graduate attributes

Engineering and the Built Environment

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Preface

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Foreword

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1 Executive summary

1.1 What is this report?

This report represents the output of the engineering and built environment discipline project for the Scottish Enhancement Theme on Research-Teaching Linkages: enhancing graduate attributes. It presents the findings of one of the nine discipline-specific Enhancement Theme projects which has been conducted in tandem with a sector-wide project.

1.2 What does it contain?

The report is based on a study of the issues arising in linking teaching and research in engineering and the built environment through a careful examination of the relevant literature on issues, strategy, good practice and successful implementation relating to these disciplines. Particular attention has been paid to the relationship with professional accreditation and the multi-disciplinary nature of our professions and the students' educational experience. A brief survey of different approaches to the linkage in Scotland was undertaken through a series of workshops, case studies and focus groups across undergraduate and postgraduate programmes by Dr Kate Carter and Dr Linda Hadfield of Heriot-Watt University. This has been supplemented in this report by international exemplars taken from the literature. The report concludes with a set of outcomes and recommendations for our disciplines.

1.3 Who should read this report?

The report is aimed at departments, and individual academics, responsible for course design, as well as those with influence in shaping policy and practice in the curriculum and academic culture of Scottish engineering and built environment courses. Its focus is on the development of 'graduate attributes' to ensure that students are getting the most out of their studies in a higher education environment where research is a key activity. The report is designed to be read by academics and policy makers to establish approaches that might contribute to an enhanced learning experience for students. It has relevance to those with teaching and research responsibility and leadership roles within a department, school, faculty or institution.

1.4 What are some of the project outcomes?

Many higher education institutions have positioned themselves as 'research led' or 'research focused' in their mission statements. While creating a view of the central role that research plays in the delivery of higher education, the perspectives gathered from academics and students does not always clearly reflect this aspiration. As described in this report, the literature does not show a natural link between research and good teaching - rather, it shows that the links need to be explicitly **created**. That said, there is a huge amount of positive links between research and teaching evident across the sector (as can be seen in the case studies in section 4) and it is encouraging that higher education in engineering and the built environment has a strong focus on the development of innovative, or creative, thinking, one of the most prominent attributes associated with this Enhancement Theme. At the end of this report generic and specific recommendations are made to help all those responsible for curriculum development in a department, faculty or institution create the links.

There is the impression from this work that research-teaching linkages and the development of related graduate attributes are already present in engineering and built environment courses, but are implicit rather than explicit - although some of this may be a presumption that the linkages are natural. It may be argued that there simply needs to be a more conscious effort to bring to the surface the research linkages and graduate attributes which are present and make explicit to the students.

Two key aspects of the creation of the research-teaching linkages have been identified in this study. Firstly, particular attention must be paid to the relationship with professional accreditation. There is an increasing awareness of the importance of linking research and curriculum from the professional bodies that accredit and support the courses and employers. This study suggests that since the development of graduate attributes associated with 'research' are comparable to the graduate competencies required for professional registration, both should be considered together. Secondly, in the engineering and built environment disciplines we must recognise the multi-disciplinary nature of our professions and therefore the students' educational experience. This is related to the definition of 'research' - so we should also recognise the linkages between traditional research, design, industry links (consultancy and technology transfer) all of which could be interpreted as valid 'research' and with each activity having their own set of attributes or competencies, albeit overlapping. This Enhancement Theme took a particularly broad definition of research at the outset, across all disciplines, to encompass these activities. In conclusion, the Report emphasises the importance of resolving these issues at departmental level.

2 Introduction and background

2.1 The research-teaching nexus

> The relationship between (staff) research and student learning is a long standing and controversial issue…. In brief, while many, perhaps most, academics and institutional mission statements see good teaching as being intimately related to quality research that tight coupling is not supported by most of the research evidence. (Jenkins, Breen and Lindsay, 2003)

Much has been written and researched on the nexus - the linkage - between research and teaching in higher education. As well as the work of Alan Jenkins and colleagues at Oxford Brookes University and Paul Trowler and colleagues at the University of Lancaster (Trowler and Wareham, 2007) in the UK, excellent studies of the issues surrounding the linkages, and examples of good practice, have been presented by Angela Brew and colleagues at the University of Sydney in Australia (Brew, 2001 and 2006). In the USA, the nature of the nexus took a related, but slightly different, approach with a call to re-establish the 'community of scholars' where teaching, research and all other activities in higher education should be intertwined. The report from the 1998 Boyer Commission, which was established to address public concerns with the plight of the undergraduate in the large research universities, proposed a radical change:

> Research universities share a special set of characteristics and experience a range of common challenges in relation to their undergraduate students. If those challenges are not met, undergraduates can be denied the kind of education they have a right to expect at a research university, an education that, while providing the essential features of general education, also introduces them to inquiry-based learning (Boyer Commission 1998)

Many US (and Australasian) universities have adopted the recommendations of the Commission and there are similar excellent overviews of good practice (McDonald, 2002). It should be noted, in preparation for the rest of this report, that the recommendations of the Boyer Commission may be wider than the direct linkage between teaching and research, requiring a consideration of other joint endeavours between academics and students in higher education. This more inclusive approach becomes particularly significant for professional, or vocational, degrees as will be discussed later in this report.

Many academics would be surprised at the range of activity and research examining the linkages between research and teaching. There are a range of established intervention strategies which can help individuals, departments and institutions to make the practical link between research and teaching and further to make that link more explicit, rather than assume that it takes place (in particular that the student is aware it is happening!). For example in the UK, the Higher Education Academy (HEA) provides an international listing of key resources to support teaching and research links (HEA, 2009). The HEA publication by Jenkins, Healey and Zetter (2007) is a good starting point for those interested in creating the link at the discipline and department level (we shall return to this issue later).

Although the research-teaching nexus has been widely discussed, the main aim of this Enhancement Theme has been to focus on the **enhancement of graduate attributes** associated with a student 'research' experience - simply, given that students can spend their undergraduate years in a research environment, educated by academics who are active researchers, how do they - or should they - be changed by the experience in a positive, and useful, way?

2.2 Enhancing graduate attributes

In the light of this wealth of practical advice and case studies (many of which are generic and could be used in any discipline), the Enhancement Theme on the development of research-type attributes on taught programmes (Jenkins , 2009) was initiated. The Steering Committee for the Theme identified a set of research graduate attributes to inform the discipline projects, guided by the work of Simon Barrie of the University of Sydney (Barrie, 2004 & 2007) who defines 'graduate attributes' as being 'the skills, knowledge and abilities of university graduates, beyond disciplinary content knowledge, which are applicable to a range of contexts'.

> Arguably the strength of this approach is that not only might it help us to distinguish higher education, but perhaps more significantly, it puts the focus on the qualities we want to develop in the student. In the context of this Enhancement Theme it shifts the focus away from the research-skills and knowledge of staff, to trying to identify what the central graduate abilities are that we want to develop in students (Jenkins, 2009)

The attributes adopted consisted of the following:

at undergraduate level:

- critical understanding
- informed by current developments in the subject
- an awareness of the provisional nature of knowledge, how knowledge is created, advanced and renewed, and the excitement of changing knowledge
- the ability to identify and analyse problems and issues and to formulate, evaluate and apply evidence-based solutions and arguments
- an ability to apply a systematic and critical assessment of complex problems and issues
- an ability to deploy techniques of analysis and enquiry
- familiarity with advanced techniques and skills
- originality and creativity in formulating, evaluating and applying evidence-based solutions and arguments
- an understanding of the need for a high level of ethical, social, cultural, environmental and wider professional conduct

at master's level:

- conceptual understanding that enables critical evaluation of current research and current research and advanced scholarship
- originality in the application of knowledge
- the ability to deal with complex issues and make sound judgements in the absence of complete data.

A key recommendation of this Enhancement Theme has been to encourage and support course teams, departments and institutions to consider how best to develop a structured approach to developing research-type attributes across the curriculum. Further, it has encouraged that this should be done in a systematic way to ensure that the final-year's focus on research-based attributes should be supported from the first year, the last needing particular attention.

This list of attributes will already be familiar (albeit in other forms) to course organisers and developers in engineering and the built environment in relation to long standing student 'competencies' for degree programme accreditation by the professional bodies. We will return to this (fundamental) issue later in this report.

2.3 A framework for discussion and curriculum design

In order for course teams and departments in a discipline to investigate and enhance curriculum development, it was decided by the Theme Steering Committee to reference a framework for broad discussion across disciplines - the various discipline projects would, if appropriate, use a common language to investigate and discuss current practice on linking teaching and research.

The framework is a tool based on the research evidence developed by Healey (2005): the model is defined by two 'dimensions' - the participant focus is from teacher to student; the research focus is from content to process. This provides four quadrants (figure 1) described as: **research-tutored**, **research-based**, **research-led** and **research-oriented**.

[Design - figure was previously used in eg RTL Overview report]

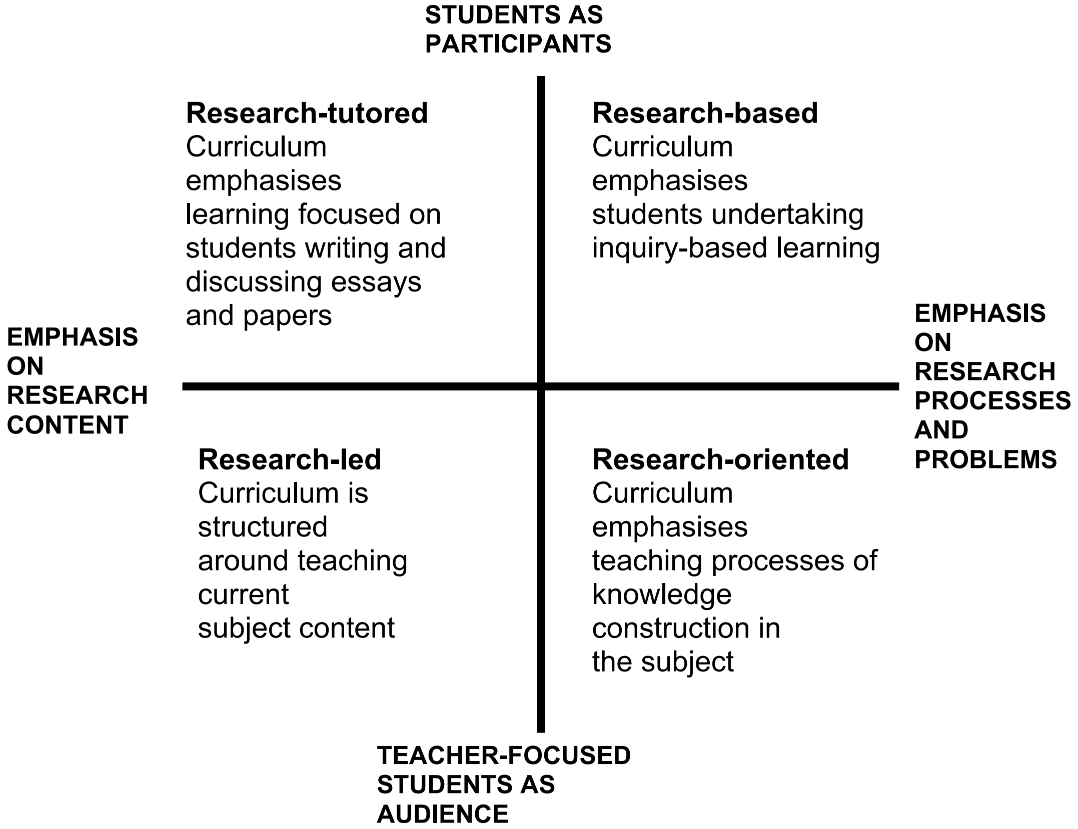

Figure 1: curriculum design and the research-teaching nexus (from Healey 2005)

According to this model, 'teaching' (in its widest sense) may be categorised into four non-exclusive quadrants, with dimensions relating to content and student engagement (University of Bath, 2007, and Bates et al, 2008).

- **Research-led teaching** treats students as an audience. It can include, for example, students learning about **research in which the lecturer or department is involved**, or research findings. The emphasis here is clearly on understanding the discipline content as opposed to research processes. General interest seminars or inspirational forward-look lectures are examples of this, as are parts of the core content of some lecture courses.

- **Research-oriented teaching** places more emphasis on developing **research processes and skills** and an understanding of how knowledge is constructed in the discipline, as opposed to simply learning 'certified' knowledge previously created. In practice, this can be usefully summarised as students acquiring 'a research ethos' and 'inquiry skills'. Courses or modules which prepare students for a research project exercise are examples of such linkages.

- **Research-based teaching**, or sometimes synonymously **enquiry-based learning** or problem-based learning (PBL), is where the emphasis is placed on 'learning in research mode', even if the outcomes for students do not result in 'new' knowledge for the subject. Students are learning in a community of researchers, with learning tasks focused on enquiry-based activities rather than accumulation of specific subject content. The role of staff in this mode is rather different from that in traditional 'lecturing' mode, and includes aspects of facilitator and partner to students undertaking such activities.

- **Research-tutored learning**, where emphasis is placed on students as participants in the **creation of research content**. Typically, this might include practical experience in research laboratories, or where students learn about research findings in small-group discussions with a teacher.

Trowler and Wareham (2007) developed a further set of categories that expand on the Healey model. Seven categories are used to characterise the ways in which the relationship between research and teaching are manifest. The first four categories reflect the four quadrants of the Healey model. The subsequent three categories evaluate institutional or departmental approaches:

1 Learners do research
2 Teachers do research
3 Teachers and learners research together
4 Research embedded in the curriculum
5 Research culture influences teaching and learning
6 The nexus, the university and its environment
7 Teaching and learning influences research

The value of the Trowler and Wareham categories is that they illustrate a spectrum from individual student research activity to institutional culture and ethos. This enables an understanding of the depth and breadth of research-teaching linkages. Research and teaching linkages occur from individual course activities through to the culture of a department, faculty or university.

Again, the Healey (or Trowler and Wareham) framework categories would be familiar to course teams and departments in engineering and the built environment. The research-tutored, research-based, research-led and research-oriented types could be identified in some form or another, perhaps in different combinations, throughout a degree programme. Or, at least, the course teams could make this identification - research shows it may not be evident to the student unless made explicit. However, as we will see throughout this report, there is an (apparent) inflexibility in the use of these types of models - indeed, others are available and these two have proved particularly helpful in the past in the study of research-teaching linkages. One issue in adopting such models as a framework in particular relates to the definition of 'research' (an issue which became prominent during this study).

2.4 What is research?

The Steering Committee for the Theme decided to include a third distinctive feature in addition to the focus on graduate attributes and the use of a framework for discussion and curriculum design: it adopted a wider view on what is meant by the term 'research'. Further, given the range of disciplines covered by the Enhancement Theme it would be surprising if the Healey framework could be used in its generic form. Much of the issues arising from the use of the framework (as we will see later) relates to what is meant by research. Much of the literature on the research-teaching nexus infers that the activity of a department (staff and students) is polarised in this way - arguably the RAE forces this behaviour. It is well recognised in the professional disciplines in particular that this polarisation is artificial.

The precise definition of research given in the Research Assessment Exercise (RAE) was the 'original investigation undertaken in order to gain knowledge and understanding'. For this Enhancement Theme, the Steering Committee included in its definition of research: practice/consultancy-led research; research of local economic significance; contributions to the work of associated research institutes or other universities and various types of practice-based and applied research, including performances; creative works; and industrial or professional secondments. Indeed, some of the Subject Panels (particularly for engineering and the built environment) for the RAE were allowed to included knowledge-transfer and 'third-stream' activities (see following two paragraphs), provided they could be demonstrated to satisfy their definition of research - the difficulty always being with the interpretation of the phrase 'original investigation'.

This extension of the meaning of research brings its own problems to working with the nexus.

Many academics in engineering and the built environment would argue that there are four **streams** to their professional activity; not only teaching and (RAE definition) research, but also applied research and technology transfer (and their relationship with the wider knowledge economy). In many cases, all four of these streams work together on the same, often multidisciplinary, project with outputs from one informing inputs to another. The issue for the engineering or built environment student is therefore not only recognising the link between teaching and research, but also the additional links between applied research and technology transfer. As a result, curricula designed to make the link between teaching and research more explicit may also need to make the equally necessary interconnections between applied research and technology transfer. There emerges a strong argument that the task in curriculum design in the professional disciplines is much more challenging. Indeed Al-Jumaily and Stoner (2000) noted in the context of the Boyer Commission that:

> …Boyer's model of academic work…recognise that the focus of the teaching/research debate neglects other equally important aspects of academic work which are specifically essential in the engineering context - namely consultation and the need for improved integration within engineering education, and beyond into non-specialist areas…

To complicate matters, there is in fact another stream of activity which must be included - that of the requirements of the profession. Many academic staff in engineering and the built environment must serve two masters - the needs of universities, higher education and quality assurance, and those of the professional bodies. Students entering professional practice-based careers tend to focus from early years on employability and the need for professional registration - indeed, these must be included in the curriculum itself. Professional registration after graduation depends upon their degree programme being accredited by the appropriate professional body, which can significantly shape the curricula. So, the requirements for professional accreditation of a degree programme in training competent engineers, and so on must also be clearly conveyed in the curriculum to the students. Here a problem arises - not only should the links between the five streams be made clear but also the distinctions. Professional accreditation requires that **all** relevant 'competencies' are included in the curriculum - one should not be substituted for another. This is a particular problem in the UK, given the demands of the RAE on academic staff.

The accreditation requirements of the professional bodies (and the built environment in particular) has resulted in what Webster (2002) refers to as 'curriculum creep' caused by the external prescription of course content. He argues that the need to fulfil the requirements of accreditation has led to less time available to devote to the development of traditional research skills. The irony here is that the employers require the very 'graduate attributes' in their employees that are associated with the 'traditional' research-teaching links (section 2.2). Development of these research attributes may be reduced if not minimised in order to satisfy the specific skills required in the workplace. The professional bodies have recognised the value of research in the education system and have started to acknowledge this through their accreditation process. Research and research-type activities are becoming more evident in the criteria for courses at both postgraduate and undergraduate levels. The following section summarises the positions and requirements of professional accreditation held by the principal accrediting bodies for the engineering and built environment disciplines and their impact on research-teaching linkages.

3 Student competencies for professional accreditation

As described in the Introduction, a feature of this Enhancement Theme has been to focus on the development of student graduate attributes. Most professional accreditation of degree programs and subsequent registration (after professional practice) of a graduate in engineering and the built environment is governed by the relevant professional bodies:

- for engineering, The Engineering Council's UK-SPEC is the standard for recognition of professional engineers and professional engineering technicians in the UK. The standard is published by ECUK on behalf of the engineering profession, with currently 36 participating professional institutions

- for the built environment professions, (a) The ARB (Architects Registration Board) has the statutory authority to prescribe the qualifications and practical experience in architecture that are required for entry onto the UK Register of Architects. Not all UK architecture qualifications are ARB-prescribed; (b) The CIOB (Chartered Institute of Building) is the standard for the development and continual improvement of educational standards for the achievement of professionalism within the construction industry. In establishing the criteria for membership of the CIOB, the Institute has developed a framework of educational requirements designed to reflect industry needs and provision; (c) the RICS (Royal Incorporation of Chartered Surveyors) has introduced a new way of working with higher education institutions which deliver its accredited courses, called a Partnership, which represents the coming together of a university and RICS to establish common goals and then to work together to achieve those goals. RICS has devolved much of what was previously controlled centrally to a series of individual partnerships with its accredited universities

In the following discussion, engineering and the built environment will be examined separately.

3.1 The Engineering Council's UK-SPEC

The UK-SPEC Standard for Professional Engineering Competence (Engineering Council, 2008a) explains the value of becoming recognised as an engineering technician, incorporated engineer, or chartered engineer. It describes the requirements that have to be met for registration, and gives examples of ways of doing this. UK-SPEC came into force in 2004 and was republished in 2008, replacing the previous SARTOR 3 rules. Many professional institutions include additional or interpretive requirements. Part of this route to professional registration includes the various levels of educational requirements for accreditation. For simplicity in this report we will only deal with the accreditation for BEng or MEng degree courses, which are required as the foundation for later professional registration.

The aim here is not to provide a full description of UK-SPEC and the full degree accreditation requirements, rather to discuss issues related to graduate attributes associated with research skills and how these are addressed by the professional bodies.

Registration as a Chartered Engineer (or progression from Incorporated Engineer) begins with an accredited degree, followed by lifelong learning and career development, usually in employment, and is based on the demonstration of professional **competence**:

> Professional competence integrates knowledge, understanding, skills and values. It goes beyond the ability to perform specific tasks. The formation process through which engineering professionals become competent generally involves a combination of formal education and further training and experience (generally known as professional development). However these different elements are not necessarily separate or sequential and they may not always be formally structured (Engineering Council, 2008a)

The so-called **threshold generic competencies**, which must be displayed for registration as a Chartered Engineer, are summarised in the table below.

UK-SPEC Threshold Generic Competencies	
	Professional Engineers must be competent throughout their working life, by virtue of their education, training and experience to:
A	**Use a combination of general and specialist knowledge and understanding to optimise the application of existing and emerging technology**
A.1	Maintain and extend a sound theoretical approach to enabling the introduction and exploitation of new and advancing technology and other relevant developments
A.2	Engage in the creative and innovative development of engineering technology and continuous improvement systems.
B	**Apply appropriate theoretical and practical methods to the analysis and solution of engineering problems**
B.1	Identify potential projects and opportunities
B.2	Conduct appropriate research, and undertake design and development of engineering solutions
B.3	Implement design solutions and evaluate their effectiveness
C	**Provide technical and commercial leadership**
C.1	Plan for effective project implementation
C.2	Plan, budget, organise, direct and control tasks, people and resources
C.3	Lead teams and develop staff to meet changing technical and managerial needs
C.4	Bring about continuous improvement through quality management
D	**Professional Engineers must be competent throughout their working life, by virtue of their education, training and experience to:**
D.1	Communicate in English with others at all levels
D.2	Present and discuss proposals
D.3	Demonstrate personal and social skills
E	**Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment**
E.1	Comply with relevant codes of conduct
E.2	Manage and apply safe systems of work
E.3	Undertake engineering activity in a way that contributes to sustainable development
E.4	Carry out continuing professional development (CPD) to maintain and enhance competence in own area of practice

The need for competency in research is mentioned explicitly in Specification B2: examples given in UK-SPEC include an ability to identify and agree appropriate research methodologies with example activities including the need to carry out formal theoretical research and carry out applied research on the job. In addition, Specification A1 includes a demonstrable ability to 'broaden and deepen own knowledge through research and experimentation' - examples of which could include formal post-graduate study.

It is clear that a successful registration as a professional engineer to UK-SPEC Specifications A and B requires competence in research, both basic and applied, with technology transfer recognised through employment in an engineering company. Specification C is related to competence in engineering management, while D and E refer to professional standards. At this stage it should be noted that Specifications A and B include demonstration of other competencies: life-long learning, creativity and design - the last two are significant and we will return to this issue later.

Eventual registration as a Chartered or Incorporated Engineer presumes formal university study on an accredited degree programme (in the majority of cases). Competency in basic and applied research and technology transfer has to be acquired somewhere and the basic graduate attributes and skills should be obtained during formal (degree level) education:

The basic graduate attributes and skills required of students graduating from an accredited degree programme (Engineering Council, 2008b) are referred to as **Output Standards** for a specific degree (for example MEng) based on specified **Learning Outcomes** which in turn must be consistent with the Scottish Credit and Qualifications Framework (SCQF) **Level Descriptors** (which are applicable to all Scottish bachelors, bachelors with honours or masters degrees in all disciplines). The combination of Learning Outcomes and Level Descriptors describe the relevant graduate attributes for a specific discipline. To many academics this combination framework seems needlessly complicated (and it is) but is designed to be more helpful for course organisers tasked with developing an accredited degree programme with providing detailed accreditation documentation.

MEng graduates build upon the basic Learning Outcomes specified for BEng graduates (which are not summarised here) but are broadly the same, requiring a deeper (more comprehensive) understanding and awareness:

> MEng degrees differ from BEng degrees in having a greater range of project work, usually including a group project. They also provide a greater range and depth of specialist knowledge, within a research and industrial environment, as well as a broader and more general educational base, to provide both a foundation for leadership, and a wider appreciation of the economic, social and environmental context of engineering (Engineering Council, 2008b)

In practice, in most degree programmes there is now no longer any bifurcation of BEng and MEng, and (in most cases) BEng students follow the appropriate MEng programme but graduate one year earlier.

In the following paragraphs the learning outcomes and associated level descriptors for UK-SPEC are summarised. Output standards for MEng degrees consist of general and specific learning outcomes.

3.1.1 General learning outcomes

In general, all graduates (whether BEng or MEng or indeed other categories) need to demonstrate: **knowledge and understanding** of their discipline and its underpinning science and mathematics with an appreciation of the wider multidisciplinary context and social, ethical, environmental, economic and commercial considerations; **intellectual abilities** through the application of science and engineering tools to the analysis of problems and a creative and innovative ability in the synthesis of solutions and in formulating designs; **practical skills** from laboratory and workshop work (perhaps in individual and group projects) and the use of computer software in design, analysis and control; and finally **general transferable skills** including planning self-learning and improving performance. In respect of general transferable skills, enhanced outcomes should be expected of MEng graduates with respect to planning, lifelong-learning, team-work and the ability to learn new theories, concepts, methods etc in unfamiliar situations.

3.1.2 Specific learning outcomes

The abridged specific learning outcomes for MEng are:

UK-SPEC MEng specific learning outcomes
Underpinning science and mathematics, etc.
A comprehensive understanding of the scientific principles of own specialisation and related disciplines
An awareness of developing technologies related to own specialisation
A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations
An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.
Engineering analysis
Ability to use fundamental knowledge to investigate new and emerging technologies
Ability to apply mathematical and computer-based models for solving problems in engineering, and the ability to assess the limitations of particular cases
Ability to extract data pertinent to an unfamiliar problem, and apply in its solution using computer-based engineering tools when appropriate.
Design
Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations
Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.
Economic, social and environmental context
Extensive knowledge and understanding of management and business practices, and their limitations, and how these may be applied appropriately
The ability to make general evaluations of commercial risks through some understanding of the basis of such risks.
Engineering practice
A thorough understanding of current practice and its limitations, and some appreciation of likely new developments
Extensive knowledge and understanding of a wide range of engineering materials and components
Ability to apply engineering techniques taking account of a range of commercial and industrial constraints.

Finally, these general and specific learning outcomes must be interpreted in conjunction with the generic Scottish Credit and Qualifications Framework (SCQF) **Level Descriptors** for all disciplines at masters level:

SCQF Level Descriptors
Demonstrate a systematic understanding of knowledge, and a critical awareness of current problems and/or new insights, much of which is at, or informed by, the forefront of their academic discipline, field of study, or area of professional practice.
Deal with complex issues both systematically and creatively, make sound judgements in the absence of complete data, and communicate their conclusions clearly to

specialist and non-specialist audiences.
Show a comprehensive understanding of techniques applicable to their own research or advanced scholarship.
Demonstrate self-direction and originality in tackling and solving problems, and act autonomously in planning and implementing tasks at a professional or equivalent level.
Demonstrate originality in the application of knowledge, together with a practical understanding of how established techniques of research and enquiry are used to create and interpret knowledge in the discipline.
Continue to advance their knowledge and understanding, and develop new skills to a high level.
Show a conceptual understanding that enables the student: • to evaluate critically current research and advanced scholarship in the discipline, and to evaluate methodologies and develop critiques of them and, where appropriate, to propose new hypotheses. • to demonstrate the qualities and transferable skills necessary for employment requiring: the exercise of initiative and personal responsibility; decision-making in complex and unpredictable situations; and the independent learning ability required for continuing professional development.

3.1.3 Discussion

It is clear that the SCQF masters Level Descriptors correspond to this Enhancement Theme's graduate attributes. The (perhaps naïve) view would be that all engineering degree programmes accredited to UK-SPEC would be expected to lead to the formation of the graduate attributes associated with research understanding, awareness and skills. It should be recalled that degrees are accredited by external experts, but experts in their specific engineering discipline. In practice, the accreditation panels work more closely to the specific learning outcomes of UK-SPEC, and in particular to the associated competencies for the specific engineering Institution. (The assumption being that if the specific learning outcomes are attained, then the general ones are by implication.)

Examination of the specific learning outcomes shows that research is **not** mentioned explicitly. This may be surprising given the UK-SPEC's stated difference between an MEng degree and a BEng degree '…a greater range and depth of specialist knowledge, within a research and industrial environment …' (p 11). The implication presumably being that the learning (and training) activities experienced by students in the realisation of the specific learning outcomes implicitly provide the necessary research attributes through the study of specialist knowledge in a research environment. Further, as in any higher education discipline, engineering academics naturally make the assumption that students do experience various features of research during their courses - an assumption which arguably could be justified given the wide range of inquiry-led and project-based activities in most engineering degree programmes. Nevertheless, the research literature on the research-teaching nexus of Jenkins, Brew et al would challenge this assumption:

> The common belief that teaching and research were inextricably intertwined is an enduring myth (Hattie and Marsh, 1996)

A recent study by the US engineering academics Prince, Felder and Brent (2007) has drawn similar conclusions. They argue that those who claim there is a link, most academic staff and managers, and those who say there isn't, higher education researchers like Hattie and Marsh, Jenkins, Brew, and so on, seem to be debating different propositions: whether research can support teaching in principle and whether it has shown to do so in practice. Prince et al then go on to suggest a number of strategies to make the research-teaching nexus more explicit. Existence of these contradictory views is supported in a report for the Higher Education Academy (Fasli et al, 2009) who conducted a small study of six science and engineering disciplines, in several institutions, from both a staff and student perspective. The results of this study suggest there is a wide variation in departmental responses to the nexus and echo the Hattie and Marsh findings. In particular, they note that there are very few 'dynamic' links made between institutional and departmental strategic planning for research and teaching.

Nevertheless a problem remains. As discussed in the introduction, this Enhancement Theme adopted a wide definition of what could be termed 'research'. It has already been noted that engineering research includes applied research and technology transfer - as well the creative, innovative activities associated with design as seen in the UK-SPEC learning outcomes. If, as Hattie and Marsh have claimed, the links between traditional research and the student experience are not automatically assured, it may be inferred that the same is true of applied research and technology transfer (also referred to as the 'third stream', or 'mode 2 knowledge' or 'consultancy-based' research). A study on linking teaching and research in the built environment (LINK 2003) noted:

> In a knowledge-based society, research and consultancy skills are key attributes in vocational and professional fields.… Graduate professionals increasingly need core skills in managing, synthesising and deploying subject-based knowledge to derive solutions to real-world problems; integrating teaching with research helps to embed these core skills. Graduates with the skills and ability to conduct research in operational settings are more likely to have the capacity to formulate problem-solving solutions based on an awareness of where to find or collect evidence, how to critically test the reliability of that evidence and how to present the conclusions and findings. (LINK 2003)

There is then an implication that in engineering and the built environment, being professional disciplines, there is also the additional need to take care to make the explicit link between applied research and technology transfer and teaching as well as emphasising the vocational and professional aspects required by UK-SPEC.

3.2 International perspectives on accreditation

Internationally there is a wide range of development on the research-teaching - these are summarised in the Enhancement Theme Overview report (Jenkins 2009). In this section, some issues related to graduate attributes, as related to professional accreditation, which have emerged from the international literature, are examined. However, it should also be emphasised that graduates, especially in engineering and the built environment, are now working more in an international environment and such issues could also have an effect on them.

3.2.1 USA

The Accreditation Board for Engineering and Technology (ABET) is responsible for degree programme accreditation in the USA. When introduced, the ABET Engineering Criteria (EC) 2000 was a major change in the requirements for accreditation - re-emphasising professional studies and design in particular. It also contains the following broad objectives:

- to assure that graduates of accredited programmes are prepared to enter the practice of engineering
- to stimulate and improve engineering education
- to encourage innovative approaches to education.

An ABET accredited programme must formulate **Programme Criteria** and **Programme Educational Objectives** that address degree program and institutional strategic plans, together with a detailed set of **Programme Outcomes and Assessment** (knowledge, skills and graduate attributes) which directly address both the educational objectives but also certain specified outcomes and a **Professional Component** (among others). To enhance the broad objectives, Engineering Criteria 2000 requires that engineering programmes must demonstrate that their graduates possess the following (known as **Outcomes 3a-3k**):

ABET Outcomes 3a-3k

- An ability to apply knowledge of mathematics, science, and engineering
- An ability to design and conduct experiments, as well as to analyse and interpret data
- An ability to design a system, component, or process to meet desired needs
- An ability to function on multidisciplinary teams
- An ability to identify, formulate, and solve engineering problems
- An understanding of professional and ethical responsibility
- An ability to communicate effectively
- The broad education necessary to understand the impact of engineering solutions in a global/societal context
- A recognition of the need for, and an ability to, engage in lifelong learning
- A knowledge of contemporary issues
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

These attributes are broadly similar to those of UK-SPEC, but less detailed, allowing some flexibility for individual degree programmes. As in UK-SPEC, no explicit mention is made about research or its links to teaching - which is surprising given the broad educational objectives. The implication again is that the research-teaching link is implicit (Prince et al 2007).

The broad objectives and concentration on graduate attributes ('attitudes' in the ABET documentation) in EC 2000 led to a significant amount of effort in the US in order to restructure and repurpose existing degree programmes. Of particular concern was how to equip the students with the attitudes and skills specified in Outcomes 3a-3k and methods of assessment of competence (Shuman et al 2005). Felder and Brent (2003) have given a detailed overview of strategies departments could adopt to ensure these attributes are addressed. They suggest that innovative teaching techniques such as problem-based learning could be adopted: students working in groups could approach a problem and '…carry out the necessary research and analysis and generate possible solutions (first seeing if the problem can be solved with currently known information), examine their fit, choose the most appropriate one, and defend the choice…then…reflect critically on the new knowledge, the problem solution, and the effectiveness of the solution process used…'. Further, the problem of assessment of student competence could include

'…research proposals and student-formulated problems…'. This is further evidence that student participation in the research process is considered implicit in an engineering degree programme. However, Devgan et al (1999) have reported how student participation in funded research could be used as a means to satisfy the EC 2000 Outcomes 3a-3k (although not without a contentious aspect as discussed in Sec. 3.2.3which does represent a more explicit strategy.

The implicit nature of the research-teaching nexus in US engineering degree programmes seem to be universally agreed to be implicit, clear and obvious - certainly in the large research-led institutions. However, concern has been expressed by the National Science Foundation (NSF) that, overall, undergraduate students were getting less exposure to research, leading to a fall in the number of students progressing to postgraduate degrees or taking up research careers in industry or commerce. There was also a belief that active participation in cutting-edge research could attract more potential students to the sciences and technology, particularly from minority students. As a result, the NSF reformed their research grant procedures to require that funded research was more widely disseminated to a wider community, including undergraduates. In addition, they initiated a Foundation-wide programme (NSF 2009) - Research Experiences for Undergraduates (REU) - which funds and supports active research participation by undergraduate students. The programme includes engineering and, as a result, there are available hundreds of case studies of good practice in providing a research experience for undergraduates; these include:

- student recruitment programmes based on research
- summer research programmes
- internships with research groups
- research experiences through civic engagement or community service
- collaborative (cooperative) research across disciplines, particularly science, and externally with industry or high schools (teachers and students)
- research skills (library research, communication skills, publication and conference preparation, research ethics)
- international research experiences
- using postgraduate students as undergraduate research mentors
- student capstone research projects.

A detailed survey cannot be given here, but the interested reader should either refer to the NSF-REU website for engineering (and built environment) (NSF-REU Engineering 2009a and b) or search the (free) American Society for Education Conference Proceedings website (ASEE, 2009) (using the search words 'research' or 'experience' are useful starting points). Examples from almost all engineering or Built-Environment disciplines can be found.

NSF also supports a number of other programmes related to promote the integration of engineering research and education, such as the Engineering Research Centres, and Research Experiences for Teachers, among others (Carriere 2005).

As well as the NSF REU programme, the Council for Undergraduate Research (CUR 2009) is very active. CUR is a national not-for-profit educational organisation with numerous affiliated colleges, universities, and individuals who share a focus on providing undergraduate research opportunities for academic staff and students at all institutions serving undergraduate students. CUR is based on the belief that academic staff enhance their teaching and contribution to society by remaining active in research and by involving undergraduates in research. The *CUR Quarterly* publication also contains several case studies in engineering.

3.2.2 Australia

This Enhancement Theme has been significantly informed by research on graduate attributes in Australia led by Simon Barrie (2004, 2007), so it is worthwhile briefly examining developments there.

In Australia, accreditation of undergraduate engineering programmes is the responsibility of Engineers Australia (Engineers Australia 2009a) through the **Stage 1 Engineer's Competency Standard** (Engineers Australia 2009b). The Competency Standard is very similar to UK-SPEC in its scope and reliance on graduate attributes for professional accreditation and registration. However, pressure from the professional body (and industry) and their national higher education institutions (by way of the Australian Learning & Teaching Council project on graduate attributes, Australian Learning & Teaching Council, 2009a) to contextualise and embed graduate attributes in undergraduate degree programmes has proved challenging for Australian institutions. In general, there are three inter-related problems evident in the Australian engineering education literature:

- innovation in teaching and embedding graduate attributes tends to be isolated and short-lived
- rigorous evaluation of impact on student learning of graduate attributes is rare
- contextualisation is limited with graduate attributes described in the literature tending to be disproportionately aligned with generic institutional lists, and poorly aligned with the realities of engineering practice.

How far this is true of the engineering and built environment disciplines is uncertain, but there is strong (anecdotal) evidence that the attitude of Australian engineering departments and academic staff in response to the parallel need for degree accreditation is very similar to those described above in the UK and the US: since the accreditation competencies must be demonstrated by degree programmes and courses the students naturally acquire the necessary attributes required by research-teaching linkages.

Nevertheless the Australian Learning & Teaching Council funded the **Engineer Meta-Attributes Project** (EMAP) (Australian Learning & Teaching Council, 2009b) which produced the Engineering Graduate Capabilities Continuum as a means of curriculum change, introducing it through a series of workshops, including case studies over the past two years with some success.

3.2.3 Issues arising

The preceding review of graduate attributes as related to professional accreditation highlights several issues which will now be discussed further. These issues relate to the nature of engineering education and the range of attributes and skills which must be covered in an accredited degree - although, as will be seen in section 3.3, similar issues arise in the built environment. These issues arise from the need for training in the professions, but it must be emphasised that each profession has their own unique issues.

Although the definition of a 'profession' can be complex, the principal characteristic (as introduced to student engineers in professional studies courses) is that it includes ethical studies and a commitment to the profession itself. The ethical aspect broadly indicates that the 'professional' has a responsibility to society and should put that responsibility before an employer or oneself. The responsibility to society differs among the professions, for example the health professions have a responsibility to the well-being of society and the legal professions have a responsibility to maintain an orderly society. The engineering profession has a responsibility to improve and grow the 'lifestyle' of society safely and to respond to the ever-changing needs of a society's economy, political climate and so on. As a consequence, the overriding characteristic of the professional role of an engineer is to innovate and be creative, as well as research and educate and so on.

It is this professional aspect of an engineer which creates a number of issues in terms of their professional education. The engineer in training must be exposed not only to 'research' - basic, applied and technology transfer - but also to their professional responsibilities and in particular to their need to be creative and innovative, principally through design. From the UK-SPEC Chartered Engineer Standard (section 3.1) competency A2 requires such an engineer to '…engage in the creative and innovative development of engineering technology and continuous improvement of systems…'. The Specific Learning Outcome for **Design** requires:

- wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations
- ability to generate an innovative design for products, systems, components or processes to fulfil new needs.

As mentioned earlier, this Enhancement Theme adopted a wide definition of 'research' to include practice-led, consultancy-led research as well as RAE returnable research, but also various types of practice-based and applied research, including 'creative works'. The last could be interpreted as engineering design. However, there is evidence (to be discussed below) that this wider definition of research could be confusing to academic staff as well as undergraduate students in that it may not be clear which attributes are appropriate or indeed being developed. Two immediate issues arise, discussed below.

As ABET EC 2000 was being released, many US institutions were considering how best to implement the capstone design project, which all students are required to complete (in their final year). Devgan et al (1999) described an early approach to this - eligible students could be considered for participation in funded research. As part of the research team, under the guidance of a member of academic staff, each student was given a specific task, which would lead to the student's capstone design project. This approach has become fairly widespread. For example, Foroudastan and Anderton (2006) also have described undergraduate research implemented as a capstone course and design project. Middle Tennessee State University's Undergraduate Research Centre promotes a culture of enquiry and scholarship for all students, integrating research-based learning in undergraduate education from their freshman year to the senior capstone experience. The example given describes the design and construction of a solar boat, where undergraduate members of the research team consider such aspects as propeller design, hull design, and solar array design, and so on. The students also research suitable construction methods and materials and select the most efficient design in each case and overall. However, this approach is becoming problematic - there is emerging an opinion that a student should not be able to replace a 'design' project with a 'research' project. In fact, the

ABET criteria do not allow substitution of research for design in an engineering program. Gassert et al (2006) have discussed this in some detail, comparing the design process to the research process. They examine the role of a student as part of a team in a major research project which mostly requires one or more design projects to complete the work, for example a significant piece of instrumentation or analysis may be required as a critical component of the overall research. Such sub-tasks can be an excellent 'research' project for the student, but in reality do not follow conventional 'design' procedures:

> Design is NOT research, which may be defined as a 'careful investigation or study, especially of a scholarly or scientific nature'. A design task MAY require research to accomplish a task, but it typically involves the integration of knowledge, not the creation of knowledge (Gassert et al, 2006)
>
> Although research experiences give student significant educational benefit, they do not replace the skills learned through a rigorous and disciplined design process. The outcomes of design are vastly different than those of research (Gassert et al, 2006)

Thus, for professional accreditation, design is an absolute requirement of an engineering curriculum, so the distinction between 'design' and 'research' is a considerable challenge if the student has to acquire the essential attributes of both. This issue has been discussed further by Cordon et al (2007) in a study of student and staff perceptions of the difference between the three processes of problem solving, design and research. They argue that because the procedure of carrying out each appears similar, many staff, and as a result students, conceptualise a single, universal model for all - but this may not be the best way to acquire the necessary skills and attributes for each. In their study they asked students to classify common engineering tasks as primarily problem solving, design or research using working definitions of each presented as evaluation tools. It became clear that the students had difficulty in distinguishing different levels of research, typically using the term 'research' to simply describe the process of gathering background information. Cordon et al found that the students responded better to four different processes: problem-solving, design, and research, with **project learning** added. Their evaluation tool is reproduced in figure 2 on page X.

So, in summary, the first issue relates back to the definition of 'research'. The Steering Committee for this Enhancement Theme responded to the need for a wider definition, specifically to include creative activities. However, it can be seen that this can cause problems since students on a professionally accredited engineering degree programme must do both (and other activities) and need to be able to distinguish between each to form explicit understanding of acquired attributes.

Characteristics	Problem solving	Design	Project learning	Research
Purpose	Remove/reduce difference between current and desired situation	Develop a device or system to meet a specific need	Uncover existing knowledge and tools to use on current task	Develop new knowledge for use in a community
Goal state	Agreement or validation that situation is resolved	Hardware or process that satisfies customer or user	Understanding of topic enough to apply on project	Acceptance of new knowledge by peers

Starting point	Undesirable or uncomfortable situation requiring change	Needs analysis, definition of specifications	Awareness that current knowledge of topic is insufficient	Inconsistencies/ incompleteness of current community knowledge
End product	Remedial action plan that can often be generalised	Tested artefact, tool, or process with supporting documentation	Added value by implementing what is learned	Theory, model, or answer to research question submitted for peer review
Timescale	Days-weeks	Weeks-months	Days-weeks	Months-years
Knowledge base	Situational expertise	Product expertise	Experience in discipline(s)	Discipline(s) expertise
Resources	Journals, newspapers, personal networking	Vendor information, patents, CAD/CAM, design of experiments	Product literature, textbooks, web pages, tutorials, consultation	Archival literature, computer modelling, data analysis, theory
Common implementation steps	Identify a problem, Engage/motivate Define problem Explore ideas Plan solution Execute plan Validate	Recognise need Needs analysis Target specs Concept design Detailed design Implementation Test/refinement	Identify missing knowledge General search Definitions/terms Specific search Critical thinking Transfer exercises Generalise	Aware of gap in knowledge Literature search Research Questions Develop method Perform study Peer review

Figure 2: evaluation tool for engineering student tasks (Cordon et al, 2007)

The second issue arises from the first. As mentioned in the introduction, the Steering Committee proposed the Healey model (Figure 1) to encourage a common language for the Theme - indeed this model, and variations, is now widely used. However, when asking academic staff, or students, to distinguish between the four quadrants of research-tutored, research-based, research-led and research-oriented activity, a (now) obvious problem arises - can the staff or students distinguish 'research' from their other activities - problem-solving, design, research, projects and so on. This problem was highlighted in the HEA study by Fasli et al (2009):

> It was clear throughout the project that the language and terminology used to describe the relationship between research and teaching was problematic. The use of the 'nexus' and the different components of 'research-led', 'research-informed', 'research-based', 'research-oriented' and 'research-tutored' were felt to be confusing and distinctions between the different types of activity to be artificial. In addition it was often difficult to distinguish activities linking research and teaching from good and effective teaching more generally, and the justification for doing so was thought to be unclear. For example, although during the course of the interviews staff were able to identify a range of approaches for using the latest research in their teaching, approaches that focused more on the process of research and

equipping students with the skills to carry out research successfully were generally only teased out in discussion. Staff in several departments did not immediately recognise these types of activities as evidence of linking research and teaching. Consequently it was difficult to identify all the incidences where research and teaching are linked, and many examples will have remained unacknowledged.

As the reader will see in later sections, other studies have noted some confusion with the use of the Healey model. We will return to this (in reality, minor) issue at the end in Section 5, since it only really relates to the definition of 'research'.

Finally, and in conclusion, it is perhaps fair to mention the studies of Joachim Walther and David Radcliffe of the Universities of Queensland and Purdue (2006, 2007). In their (ongoing) study they argue that 'targeted' instruction - that is, trying to match curriculum design and instructional style to learning outcomes and competencies - can conflict with behavioural learning, particularly in engineering education where many skills and competencies (basic knowledge, problem-solving, design, research, projects, professional studies and so on) have to be covered. They have focused on two (very well appreciated) examples of accidental learning: **grade fixation** and **disinclination to seek help**. Real-world examples from graduate engineers working in industry have been presented:

> I had an experience where a bonus system in the customer service of the company rewarded new customers in a certain region more than contracts with existing customers. I found myself and others automatically focusing on these customers - in the long run this had a detrimental effect on the company. But I think that was caused by this fixation on grades at university - we were basically conditioned to act like that
>
> During my work experience I realized that my course broke my habit of asking questions. It was not encouraged. More the opposite, it was implicitly punished - there was always a good chance that you would look stupid when you asked a question. Or when you said something that was not entirely right the lecturer would have to correct you.… I was working with a group of electrical engineers. And they kept using this one acronym - it was the name of some device. I could not have known that. But I did not ask. My first reaction was 'as an engineer you should know this' and I would try to find out by myself. That turned out to be a problem. The conversation advanced to a point where I could not really ask anymore - I should have just asked in the first place and it would not have been a big deal

This concept of accidental competency should not be surprising to many students who are taught about the role of the engineer in society and the Law of Unintended Consequences!

These issues - the distinction between the various processes which must be learned by students on an accredited degree program, the language used in describing the research-teaching nexus and the notion of accidental competencies - should not be ignored.

3.3 Built environment professional accreditation

The built environment professions have very similar issues with the research-teaching nexus as engineering - however there are in some sub-disciplines subtle differences. A fairly detailed study has been published by the LINK project (Linking Teaching with Research and Consultancy in the disciplines of Planning, Land and Property Management, and Building) funded by HEFCE (LINK). One of the outcomes of the project was that the disciplinary aspect of the nexus was particularly strong with the conclusion that the vocational nature of the profession meant these areas would typically be research-based rather that research-led. The professional practice and other accreditation bodies tended to put more emphasis on student attributes related to using the findings of research than the experience of conducting research. However, it was also felt that the multidisciplinary nature of the discipline meant that it was a rich area for the integration of teaching and 'research' (although care had to be taken on its appropriate definition). Nonetheless, the QAA benchmark statement for Construction, Property and Surveying (QAA, 2008), which was developed with reference to the Centre for Education in the Built Environment, the Construction Industry Council, the Chartered Institute of Building (CIOB) and the Royal Institution of Chartered Surveyors (RICS) among others, does include 'research' in the benchmark (albeit without definition). For example, students may acquire subject-specific and generic skills which include 'wider research skills to aid in the development of a cumulative element of original work'. Further, a threshold standard for generic skills requires that students will be able to 'use methods for acquiring knowledge and apply appropriate research strategies and methods' while a more typical standard would require students to be able to 'evaluate the appropriateness of various methods of knowledge acquisition and select appropriate research methods and evaluate a range of sources including current research'. This infers a research-based emphasis, where students learn research skills rather than conduct their own research.

A particular issue for the built environment professions appears to be the role of 'consultancy'. Griffiths (2004) has noted that there is a tension between research and consultancy - principally whether consultancy generates new knowledge or is just the application of professional knowledge to particular cases:

> Much of the 'research' activity in built environment departments consists of feasibility studies or evaluation studies for government departments, local authorities, development agencies and other (usually non-commercial) bodies. Tensions about the scale and management of consultancy activity are, therefore, often close to the surface. One of [the] difficulties in resolving these tensions, however, is that, in the sphere of applied knowledge production, it is not possible to sustain a simple distinction between research and consultancy. In practice-oriented fields, the provision of expert advice may not entail the kind of rigorous, hypothesis-led, methods of empirical science, and may not lead to published outputs in recognized academic journals. But it may well involve the clarification and reworking of basic concepts, the testing out of ideas and methods, and the application of accepted principles to new contexts, such that it does constitute valid new knowledge production of this third, applied kind. The boundary between research and consultancy is, therefore, not an easy one to draw.

Consultancy, of course, is also conducted by engineering academics, and often this can involve discovery-led research which can be published, but seems to be a stronger issue in the built environment. That consultancy in the latter is a significant factor is further highlighted by Griffiths - many staff teaching on built environment degree programmes came into higher education on the basis of their professional practice experience and there is an amount of ambivalence to 'research' since advances in practice are rarely driven by discovery research. As a result, there is a natural tendency to focus on imparting to students professional skills rather than those of critical, inquiry-led knowledge creation. This tension can be seen by students in final year projects (or dissertations). Despite these inhibiting factors, the LINK project noted that the methods of teaching in the built environment (indeed as in engineering) such as projects, design studios and problem-oriented activities are inquiry-led and a good source for learning research skills as well as the potential for incorporating staff research.

In the following, some additional issues related to 'architectural' education and 'surveying' education are briefly discussed:

3.3.1 Architecture

ARB prescriptions of qualifications: Criteria
The underlying framework for the ARB Criteria is the European Union's **Architect's Directive** which sets minimum requirements for the length and core areas of study across the European Union to facilitate the provision of architectural services across Europe.

The prescription of architectural courses is determined by the ARB and there is an emphasis on design in course structures. In the Introduction to the ARB Criteria it is stated that:

> Students must also be given the opportunity to pursue related, specialised, or optional studies …that, for example, link architecture with other subjects, **emphasise research**, develop specialisms and promote advanced degrees. However, such initiatives must not compromise the key requirement that all students receiving a qualification must meet all the criteria. (ARB prescription of qualifications)

This demonstrates the inherent emphasis on design, and therefore creativity, in architectural courses. This is of course very similar to the design aspect of the training of professional engineers.

When the core criteria are examined, they closely reflect the graduate attributes associated with Research Teaching linkages. Students are required to:

- integrate knowledge of social, political, economic and professional context
- understand theory in a cultural context
- systematically test, analyse and appraise design options, and draw conclusions which display methodological and theoretical rigour
- critically appraise and form considered judgements about the spatial, aesthetic, technical and social qualities of a design

among others.

However, academics in architecture have been encouraged to submit practice-based (in this case design) research as part of the RAE and as a consequence there perhaps needs to be added clarity as to what is meant by research-teaching linkages in architecture, particularly from the students perspective (and particularly in any institutional strategies which encourage such linkages). A useful discussion of this has been given recently by Roberts (2007).

Roberts points out that the research-teaching nexus strongly depends on the individual discipline and that this is particularly true in architecture:

> The research-teaching link in architecture is likely to be particularly complex given the multi-disciplinary nature of the subject. There is no single specific research methodology that might typically be used, rather architecture utilizes and applies the methods and knowledge base of other discipline areas, including the human and physical sciences, the humanities and the fine and applied arts. As with other built environment subjects, research is likely to relate to application of knowledge, rather than the generation of new knowledge (Griffiths, 2004). Researchers may apply principals from pure science, for instance by investigating how buildings respond to environmental and climactic influence, they may apply principals of philosophical thinking to architecture, or they may use techniques of the historian or social scientist

Rendell (2005) and Jenkins et al (2006) have highlighted four areas in which architectural research could be identified: building science, social science, humanities and art and design. Roberts analysed the 2001 RAE outputs from schools of architecture and found that humanities and building science formed the largest proportion of research outputs. There were few submissions of 'design as research' to the Built Environment Panel (although some to the Art and Design Panel), it perhaps being felt these were inappropriate for the RAE.

The issue of 'design as research' is discussed in depth by Roberts: 'The process of designing is one of synthesis and integration of knowledge from a variety of sources, something that Boyer (1990) refers to in other fields as the scholarship of integration'. It has been suggested that this is not research in the traditional (certainly RAE) sense and the concept that practice-based research is valid (even if measured by the rigour of traditional research) is contentious. Of course, this is very similar to the distinction between research and design discussed in the above for engineering. The important point from that discussion was that the distinction should be clear to the students (certainly as part of their professional formation).

Roberts analysed a number of case studies in architectural education commissioned from the Centre for Education in the Built Environment to analyse the nature of the research-teaching linkages according to Healey's model. His analysis of the case studies showed the following:

- all adopted a student-centred approach
- none of the case study participants expressed a desire to transmit their own research to their students
- apart from one case where the students were engaged in the process of research, in all others the research undertaken by the students was a means of developing some other learning outcome
- according to the Healey model, all fell mostly under the heading of research-based.

Three further points were noted by Roberts:

- In all of the case studies an assumption was made that 'designing does constitute researching': 'design *project* work typically requires the student to adopt an inquiry based approach to learning, which will often involve the undertaking of research type activities':

One issue particular to architectural education is the students' participation in design project work, which in certain cases may constitute a process incorporating a number of elements that might also be found in research. The making and testing of propositions based upon evidence derived from experimentation as well as library resources is commonly found within architectural education.

- There was some difficulty in using Healey's model:

  It is possible that the model may need to be adapted to reflect the specific nature of the discipline of architecture, in order to distinguish between situations where students apply and interpret a tutor's research interests into their design thinking, and where students are undertaking more self-determined research through design.

  In terms of Healey's model, teaching of this type could be described as being research-based - whereby a student uses research methods, but does not replicate the content of departmental research. **But does student project work really constitute research**? (emphasis added)

It can be seen that the same issues with the differences between design and research are evident as in the case of engineering in the preceding, and further that Healey's model would need to be adapted (certainly to help academics in coming to terms with the research-teaching nexus) to somehow reflect this. The difference is arguably more challenging in architecture.

3.3.2 Surveying

RICS (Royal Incorporation of Chartered Surveyors)
The RICS published a pilot project (Wood and Ellis, 2007) to evaluate research and innovation in the courses it accredits. In 2005 (RICS 2005) the RICS Education and Training Department published its *Policy and Guidance on University Partnerships*. The participating institutions (in the partnership) are required to demonstrate how students are exposed to research and innovation. The RAE was explicitly mentioned given that a minimum research standard in a university was defined according to RAE 2001. Wood and Ellis surveyed the surveying profession together with academic staff views on the use of the RAE definition of research as a requirement for departments to gain accreditation (since RICS felt that the profession was being starved of new blood if the research activity was too narrowly defined). Overall, the effect of the RAE definition of research, and the requirement to carry out this type of research from an institutional funding perspective, was felt to be negative and detracted from teaching this particular practice-led discipline. While it was generally felt by staff that both the research process and current research could nurture undergraduate studies, many also expressed the view that RAE-type research had marginal relevance when compared to case study, market-based or professional development activity. Further, it was suggested that the RAE distorted academic studies in surveying: 'At its extreme, this…can lead to an RICS partnership university which has a top RAE rating, but where the research subject matter has, at best, only tenuous links to the surveying knowledge domain'. The Wood and Ellis study recommended that there should be move away from an evaluation of partner universities based on RAE performance, towards a teaching environment that encourages innovative approaches:

> Following extensive consultation, RICS has decided that the threshold standard should no longer be based solely on the RAE. Instead a portfolio

approach is being introduced to allow universities to demonstrate the many ways in which innovation through teaching can be delivered (From RICS guidance note on the threshold standard for research and innovation).

3.3.3 CIOB (Chartered Institute of Building)

Research does not dominate the accreditation criterion which reflects a more vocational nature to the courses accredited by this organisation. However, there is clear reference to some of the graduate attributes associated with those of research-teaching linkages. The lack of a link between these attributes to research-type activity perhaps exposes a mismatch in the accreditation process. The CIOB mentions research in relation to postgraduate degree accreditation and only briefly for undergraduate courses: 'To plan, implement and conduct a programme of research and to demonstrate an understanding and development of innovation in practice in this study' (CIOB, 2007). It is not clear what is meant by research here, but by implication.

3.3.4 Discussion

It should be clear from the above that in the case of the built environment disciplines in particular there is a particular tension between 'research' and 'teaching' if the (narrow) RAE definition of research is used - perhaps as expected. The wider Enhancement Theme definition is of course more helpful, but it is clear that additional effort must be put into course design to ensure that students are aware of the specific differences between the attributes they acquire through research, design, consultancy, practice and so on - indeed similar issues to those found in engineering.

Researchers on the research-teaching nexus in the built environment disciplines have clearly highlighted the issues related to the additional tensions between teaching and research, design and practice. Frank and Roberts (2007) have highlighted the diverse perspectives of research-led teaching in planning and architecture and introduced the notions of the 'Research and Practice Nexus' and 'Research and Design Nexus' in each discipline, both of which also have clear application to engineering. In the context of design they distinguished possible distinct student activities such as 'Research **into** Design', 'Research **for** Design' and 'Research **through** Design'. The first encompasses a study of the design process itself while the second covers student background research for a specific design project. 'Research Through Design' would be (in the Healey framework, section 2.3) student-focused research-based activities, suggesting the explicit interpretation of inquiry-based learning as 'students using the process of designing as a means to advance and develop knowledge'. Student Research through Design has the potential to expand the boundaries of knowledge, to innovate, to involve technology transfer and, specifically in architecture, is subject to peer review - all characteristic of the type of research attributes we would expect the students to acquire, even if not gained through what is understood as conventional (RAE) research.

Further, in a study of research knowledge transfer into teaching in the built environment, Senaratne et al (2005) have similarly emphasised the wider dimensions to the 'research'-teaching nexus:

> The Built Environment falls under vocational and applied science disciplines as opposed to pure sciences discipline. Teaching in the BE discipline tends to be research-informed rather than research-led. Consequently, the academics place more importance on the synthesis and application of

knowledge compared to knowledge creation in this domain. In fact, knowledge is mostly created during the application (on the job) compared to the research laboratory, lecturer's office or classroom. This suggests a different dimension i.e. the importance of creating an industry link.

4 Case studies

The remainder of this report focuses on case studies of good practice. The more detailed **case studies** and briefer **snapshots** have been taken from a study undertaken as part of this project by Kate Carter and Linda Hadfield of the Department of the Built Environment, Heriot-Watt University, and combined with several outline **international exemplars** taken from the literature.

As part of the Carter and Hadfield case studies and snapshots, willing lecturers from engineering and built environment sub-disciplines across Scotland were interviewed about how research and teaching are linked. Lecturers were asked to focus on a specific course or module so that sufficient detail about the course or module's structure could be elucidated and also asked which of the four links between research and teaching in the Healey framework (section 2.3) were evident. These examples are all considered good practice in the way research enhances teaching. This is not a reflection on the quality of teaching that exists across the engineering and built environment sector, but a range of examples where research and teaching are linked to enhance the student experience, potentially leading to the development of graduate attributes.

The international exemplars have been selected from several countries - many were selected to show how common practice in many engineering and built environment courses could be enhanced (see the discussion below). The exemplars are not described in detail, since the interested reader can readily access the original studies referenced here.

In both the case studies and international exemplars the wider definition of research adopted by this Enhancement Theme has been used (section 2.4) to include 'creative works', specifically design. However, it has to be understood that these are complimentary and, as discussed in section 3.3, generally both part of an accredited degree program. Both research (in the RAE sense) and design should be present to achieve an appropriate broad range of graduate attributes which are in harmony with the competencies or attitudes required for professional accreditation. So, in the following, both research and design examples can be distinguished. However, in the design of a holistic degree programme, both should be present.

In the following, the case studies, snapshots and international exemplars are presented in the style used in the Physical Sciences study (Bates et al, 2008) - that is, chronologically from student entry through to graduation (or 'from fundamentals to frontiers'). This has been slightly modified to suit the current disciplines. Further, in using this chronology it should be noted that some examples (particularly the international exemplars) overlap in terms of progress through a degree - for example where students participate in a research project in an earlier year for project skills preparation, and discovering the nature of research, then move on in the same project to carry out individual or group research. In particular, project skills preparation may be done at the same time as individual and group projects: and in some cases group projects contain sub-projects for individuals.

It is also worth noting at the outset that professional skills preparation and individual and group project work will be familiar to most academics involved in engineering and built environment courses which are professionally accredited. However, the aim here will be two-fold:

- mostly the style (and/or content) of the case studies and snapshots will be familiar to most engineering and built environment academics. The aim here will be to explicitly identify practice within the Healey model

- the international exemplars have been mainly chosen to demonstrate how familiar practice (in particular projects) can be enhanced to introduce new (or novel) practice or integrate a range of attributes (other than just those associated with research).

The case studies (CS), snapshots (S) and international exemplars (IE) are summarised below:

4.1 Implementation in first-year classes	4.1.1 University of Strathclyde, Mechanical Engineering, Problem-based learning (CS) 4.1.2 Tufts University, USA, Engineering, Windows on Research (IE) 4.1.3 Washington State University, USA, Mechanical and Materials Engineering, 'CURE Boot Camp' (IE)
4.2 Transferable and professional skills development	4.2.1 University of Abertay Dundee, Civil Engineering, Foundation Research Skills (CS) 2.2 Rowan University, USA, Engineering Clinics (IE)
4.3 Learning through case studies	4.3.1 Glasgow Caledonian University, Audio Technology, Staff research (S) 4.3.2 University of Strathclyde, Architecture, Urban Design (CS) 4.3.3 University of Dundee, Architecture, Design Collaboration (CS)
4.4 Internships and placements	4.4.1 Lafayette College, USA, Engineering, EXCEL Scholars program of undergraduate research (IE) 4.4.2 University of Maryland Eastern Shore, Engineering, Complete Research Cycle (IE)
4.5 Project skills preparation, learning what research is	4.5.1 Robert Gordon University, Architecture, Research skills in Design Philosophy (S) 4.5.2 Heriot-Watt University, Civil Engineering, Advanced Design Studies (CS) 4.5.3 LeTourneau University, USA, Undergraduate Student Research Laboratory (IE) 4.5.4 University of Queensland, Australia, Mechanical Engineering, Linking Engineering Management and Research (IE)
4.6 Individual research project	4.6.1 Heriot-Watt University, Civil Engineering, Flood Management (S) 4.6.2 University of South Carolina, USA, Chemical Engineering, Research Communications Studio (IE)
4.7 Group research project	4.7.1 University of Edinburgh, Mechanical and Chemical Engineering, Group Design Project (CS) 4.7.2 University of Edinburgh, Architecture, Environmental Design (S) 4.7.3 University of Canterbury, NZ, Civil Engineering, Compulsory Research Project with Cultural Engagement (IE)

4.1 Implementation in first-year classes

4.1.1 Case study: Problem-based learning

This case study describes part of a first-year module on design delivered within the Mechanical and Aero-engineering programme for the BEng and MEng degree. It is taken by approximately 140 students and managed by two principal lecturers with support from other academic and technical staff. The module accounts for almost one-third of the first-year curriculum.

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Description of the course

This module was introduced as part of a radical restructuring of the first-year curriculum over a decade ago. It was introduced not only to bring aspects of engineering design into the entry year, but also to replace more conventional large-class lectures on materials and manufacturing. It was felt at the outset that this had to be based around a significant hands-on and practical element. A substantial part of the module is comprised of Mechanical Dissection (Sheppard, 1992) - a progression of activities based on the dissection, or disassembling, of a component from a motor car (although any other large engineering artefact could be used). The aim was that the students should learn, through discovery, the rationale behind that component's design. During their first year, each student is assigned to a group of four: they work in the same group in most other modules throughout the year, for example even in the large-class format of core engineering science subjects. The class is arranged as a series of tasks throughout the year. The student groups are assigned to one of four cohorts going through this series, of which the tasks associated with mechanical dissection is one. Each cohort starts at a different point of the cycle, and thus will undertake the mechanical dissection at a different stage of their first year.

It should be noted that students are responsive to the need to carry out a mechanical dissection of a car before enrolling on the course - this type of activity is highlighted throughout the application/interview process. During initial meetings with the class, the structure of various tasks is explained to the students so that they are aware when in the year they will be working on the car dissection. At the start of their Mechanical Dissection task, students will spend a couple of hours, three groups at a time, selecting a part of the car (for example the front or rear suspension, or a part of the braking system) and removing that part. The following day each group meets with two lecturers to discuss the physical principles behind the component's function, and to select a couple of parts for further examination. Usually these parts are examined under the microscope to ascertain the materials and manufacturing processes involved. The students then have three weeks to discover/research the function, physics/mechanics, manufacture and design of these components. It is an important part of Mechanical Dissection that they will also need to research, and explain, topics not covered elsewhere in their first-year course. Each group has to produce a poster explaining its research on the components - the group presents its draft poster to two members of staff, who discuss content and advise the students if any further work is necessary. Each group then have to produce a brief presentation (covering the same material as the poster) for a plenary session for the whole cohort. At the plenary session two students from each group are chosen at random and present their work, in the form of a description of the component, to the rest of the students. After their presentation, each group has to respond to questions from one of the other groups of students.

Links between teaching and research

The class was designed at the outset to give entering students an experience with enquiry-led learning and the processes of discovery, research and integration of engineering concepts. There are no real set goals in the task, other than to discover the design, manufacture and engineering behind some component of a car and to present these to academic staff and fellow students. The tasks associated with producing the poster and presentation also build skills in teamwork and communication and encourages independent (as well as group) learning. A particular aim was to let the students also discover how the theoretical work they cover in their other classes in the first year is relevant to real engineering. Notably, the students may not yet have covered some of the required mechanical or physical concepts and ideas in other classes - but this would allow them to make real connections at a later stage. The students also have to research engineering concepts not covered in their formal classes (possibly not covered during the whole course) and to understand well enough to explain during an interview (during the poster session) and whole-class presentation. Perhaps the most useful research attribute learned by the students, at an early stage, is that they can cope with working successfully with the unknown.

Course assessment

As described above, the course is assessed formally through a poster presentation to academic staff and by a presentation to the whole class. However, due to the frequent contact with academic staff during the task, there is a considerable amount of informal formative assessment.

Course evaluation

The course is continually monitored by the staff involved, and modified as appropriate. An independent review of the outcomes of the course was undertaken by the Higher Education Academy, Engineering Subject Centre (Barker, 2005).

Effect on student experience

A significant aim of the class was to give the students an opportunity to do something practical, but fun, in the context of real engineering, which many of them will not have experienced before. The students, at the outset of their engineering studies, must learn in a new mode by investigating open-ended problems themselves, and as part of a team, rather than through formal lectures. In the real sense of problem-based learning they may never encounter some of the engineering concepts they discover during their formal classes anywhere in the course. At the outset the students experience multi-disciplinary small-group discussions (and more formal interviews) with expert, subject specialist academic staff - although this is done through a supportive atmosphere with the staff understanding that the students are going through a process of discovery. The independent review of the class (Barker 2005) highlighted a 'strong perception that it improved their engineering knowledge, improved their presentation and other skills and that it enhanced their motivation to learn and was enjoyable because it was a "hands-on" exercise and linked theory to practice'.

4.1.2 International exemplar: Tufts University, USA - Windows on Research

Civil and Environmental Engineering, first-year students.

Source: Swan, C S (2004) *Case Study of a Project for First-Year Students that Integrates Research and Community Service*, ASEE Annual Conference & Exposition, Salt Lake City

Tufts University runs several advising programmes for entering first year students; one is the Windows on Research course which links a small group of students with an academic adviser. The aim is to expose the students to a research topic in which the academic adviser is involved, or wishes to explore. The aim of the course is not only to introduce students to the process of research, but also to provide an opportunity for student advising. Swan (2004) has described one such course in the field of environmental engineering.

In Swan's course, the research project was to investigate how waste materials are being, or can be, reused in the State of Massachusetts. This project was designed to expose the student group to technical aspects of recycling but also the economic, social and political factors involved and, through the collection of data, expose them to the local community. The students and adviser met once a week to review available research. These meetings involved (1) small lectures (on US and Massachusetts recycling and reuse programs), (2) a short course on data collection methodologies led by university library staff who specialise in engineering resources, (3) laboratory experiments on creating synthetic aggregates from waste plastics, and so on, and (4) general academic advising. The research component of the project involved the collection, analysis and synthesising data on the recycling behaviour of communities in Massachusetts. Data on demographics (community information) waste handling and recycling from over 300 towns and cities (reported to the Massachusetts Department of Environmental Protection) was gathered and analysed - the students had to explore all available resources, not only from the various libraries but also from contacts with state and community officials. The students had to process the data to relate the type of community to recycling behaviour and present using statistical analysis tools. In fact, in the study reported by Swan, the students found no clear relationship between per capita income and recycling rates! The final deliverable was a poster to be presented at a symposium - the original aim had been to write a report for community policy makers, but time did not allow.

Swan reports his overall experience of the course was positive: the student work led to a set of data which could be reused and further enhanced. Although the students received little academic credit, they did carry out the research; the author felt that it would be beneficial to have more meetings on the research component outwith the context of first-year student advising.

4.1.3 International exemplar: Washington State University, USA - 'CURE Boot Camp'

Mechanical and Materials Engineering, first-year students.

Source: Bahr D (2009) *A One Week Intensive Short Course for Introducing Lower Division Students to Undergraduate Research*, ASEE Annual Conference & Exposition, Austin

Washington State University (WSU) is a rural residential college and, like many other US public research schools, has problems with retention rates in STEM fields - for example freshman to senior retention in engineering is around 50 per cent. However, it has been found that retention rates can double with student participation in undergraduate research, particularly if they occur during the first two years of the college experience so that the students are more prepared to work in a research group in later years for their final year ('capstone') project. This approach is fully in line with the ideas from the Boyer Commission report, which is being adopted in many of the US's research universities. Retention at WSU has been shown to particularly improve among transfer students from community colleges. WSU developed the Cougar Undergraduate Research Experience (CURE) Boot Camp to address these issues. (The Cougars are the college's football and basketball teams). Bahr (2009) has described the CURE Boot Camp in more detail:

CURE is an optional, intensive one-week programme which runs at the start of the summer after courses and examinations have just finished: it is part of an advising (mentoring) program during the academic year for first-year (and transfer) students. Students are given a stipend to cover additional costs during the week - after successful completion the students are considered certified and, together with the mentoring academic, can access additional matching funds for continuing research. As reported by Bahr, this stamp of approval is very advantageous to the student in later years. CURE combines short lectures with active learning tasks: two topics are covered each day with small group tasks after each lecture, such as identifying resources for a specific research topic, separating popular sources from peer-reviewed literature, writing a single-page essay surveying academic research opportunities and so on. The short lecture topics cover:

- finding an adviser, interviewing with faculty and creating a résumé geared at research and selection of a research project (this is tied in with presentations from faculty around campus on their research activities)
- discussions of intellectual property, scientific integrity and ethics in research
- understanding the difference between popular, textbook, and peer-reviewed literature
- selection of information sources and use of library resources
- making and presenting posters for research symposia
- improving technical writing skills
- improving laboratory notebook techniques
- developing time management skills
- long-term career options for research, including how federal and state funding options impact research activities.

These are described in more detail by Bahr, but most are familiar. With the particular student cohort studied by Bahr (32 students) 50 per cent joined a research group after the program, attending meetings with mentoring academics, postgraduate students and research staff, regularly pursuing research in their adopted groups. Students reported that they were motivated by the idea of summer boot camp activities and that the programme helped them find out what it was like to be a researcher and to get hands-on experience early in their course. Those students who did not immediately join research groups reported that they found they did not have the time to personally commit to research without credits.

4.2 Transferable and professional skills development

4.2.1 Case study: Foundation research skills

This case study describes a foundation module taken by all civil engineering students in the first year of their four-year honours degree. The module, Introduction to Civil Engineering (BN0707A), is part of the BSc Honours Civil Engineering course. The module lasts 30 weeks and is worth 30 credits; typically 25 students are registered for the module. The module is delivered through team-teaching - an integrated set of instructors (teaching manager, IT and library staff, and subject-specific researchers) each contributing their unique skills and perspectives in order to communicate professional development skills to students through current research content and practice-based studies. The students primarily work in groups which change according to task together with some individual work - no formal lectures are involved.

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Description of the course

The module runs over two semesters with different skills development in each. The first semester concentrates on generic basic skills development, while the second is subject specific, allowing the students to experience the work of a graduate engineer through a civil engineering project simulation:

In the first semester, students are given various tasks that are intended to help them improve certain skills. Skills that are targeted include self-awareness, critical thinking, reflection, and planning, the ability to transfer knowledge or draw on experience from one situation for use in a different situation. These are developed in the context of studying in a higher education environment as part of a team and as an individual. The students work in small groups on some tasks, but the mode of working can vary. For example, in an exercise on leadership and teambuilding several students are selected to be group leaders; these leaders then select a team to work with. One group is selected as an observation group who are briefed separately with different objectives. At the end of the task groups critique each other. Students are encouraged to recognise their learning style and to effectively manage their own strengths and weaknesses during each task. The tasks in this semester emphasise the general nature of professionalism before more topic-specific information is covered in the second semester. At the same time, students also work individually to develop their IT and library skills: goals for students include achieving an IT standard and being able to critically appraise information. This part of the module is taught by a lecturer working with two IT specialists and a subject librarian. The same teaching team works together every year, as much as possible.

The second semester is a civil engineering project simulation. Students learn what a civil engineer does in a typical project; they are also introduced to higher level research activities and how these feed into a civil engineer's job. To begin with, the instructor forms groups of five students so that they contain a mix of student achievement levels. Working in these groups, students are expected to do the preconstruction work for a project related to a new leisure centre for the university. Students have tasks that they must complete on a weekly basis: the project includes costing, design, and health and safety matters. The teaching team acts as the client team; student groups meet with these pseudo-clients to formulate a suitable brief. A group's project brief is therefore based on the questions they ask the client team. During the project development academic staff also present sessions describing research and construction technology-transfer from the Division's activities relevant to the project scenario. The link between industry and research is described through lectures and online resources. The project is run as a simulation of an open plan office environment. The instructor acts as a manager to observe and guide students in the right direction; students receive feedback from the instructor weekly. During class time students may go to the computer lab or library, or consult members of staff as they feel is necessary - appropriate communication within groups and with the instructor is encouraged, for example, distributing email correspondence or discussions to all group members is emphasised. The instructor also encourages students to think through questions before coming forward with them, and to manage time effectively. The second semester work concludes with a presentation of the project portfolio by each group.

Links between teaching and research

The students develop a range of research skills through the module: information retrieval, critical appraisal, reporting their findings in oral and written presentations, and working with a team. They also experience other graduate skills relating to the job of a civil engineer through the project simulation. The students also have opportunities to review the current literature on topics such as sustainable urban drainage systems designed with sustainable construction and methods for reducing energy consumption through construction among others.

Students are not developing new research, but the course is taught in a way to give students the experience of someone doing research. The civil engineering project is well understood and as a result the academic staff can give students more effective feedback than if the students were researching an unknown question or doing primary research. The design of the course has drawn on CEBE case studies and the module leader discusses content with academics in this subject, as well as educators in other disciplines, and with practitioners in industry to determine what they consider important. Industry appears to value employees who can articulate clearly what they have done and why, can speak and write clearly and coherently, and who are able to learn from their experiences - the module has been designed to get the students to start thinking about these attributes in a first-year course.

Course assessment

Students complete four summative assessments based on their course work. The first is a written report about the history and development of engineering and the role of contemporary civil engineers and is worth 10 per cent of the final grade. Site visits and professional body visits are also included in this report. The second assessment is an IT portfolio primarily covering information retrieval and handling; students must also demonstrate competency in the use of Microsoft Word and Excel, critically review websites, and research subject-specific databases (such as the Barbour database). This assessment is worth 20 per cent of the final grade. The third assessment is a personal development and planning portfolio: students critically reflect on tasks they have done in this course, (leadership exercises, setting objectives), tasks that they will have to do as a professional civil engineer - this assessment is worth 30 per cent of their grade. The final assessment is the project simulation - this is worth 40 per cent of their final grade. Students are evaluated on how successfully they complete this project.

Course evaluation

The module content is continually reviewed by the teaching team. There is also peer review of the course: in particular, the Division Leader observes sessions during the project simulation. Accreditation teams also review the student work when appropriate.

Effect on student experience

Students start their development as professionals, improving their critical thinking and reflective thinking instead of accepting information without question. Students become better at determining if facts are relevant or correct; this is seen as important for new first-year students. The staff involved can see students becoming more articulate, thinking wider and deeper and more clearly and accurately about topics. Students begin to ask questions that are well thought out instead of sporadic. For all those who finish the first year, this teaching method clearly works - students who attend the course pass successfully.

4.2.2 International exemplar: Rowan University, USA - Engineering Clinics

Engineering, first to final-year students

Source: Sukumaran B et al (2006) Engineering Clinics: An Integration of Research into the Undergraduate Engineering Curriculum, *CUR Quarterly*, volume 26, number 3

Rowan University is a relatively new institution - the Rowan Engineering Program was started in 1996 with a goal to develop an innovative curriculum. The programme uses innovative methods of teaching and learning designed to better prepare students for careers in modern engineering; it also fosters a strong research environment. The main feature of the programme is a set of Engineering Clinics (Sukumaran, 2006) - common classes for all engineering disciplines. The Clinics are a course program that runs from first through to final years and planned to incorporate more hands-on design in the curriculum. They allow students to practice a wide range of engineering skills in a multi-disciplinary environment through the development of design and research skills throughout their four-year student career. The core objectives of the Engineering Clinics are:

- demonstrate an expanded knowledge of the general practices and the profession of engineering through immersion in an engineering project environment of moderate complexity
- demonstrate an ability to work effectively in a multidisciplinary team
- demonstrate acquisition of new technology skills through use or development of appropriate computer hardware, software, and/or instrumentation
- demonstrate understanding of business and entrepreneurial skills by developing business, marketing, and venture plans, or other approved instrument

- demonstrate effective use of project and personnel management techniques. integrate engineering professionalism and ethics in their work and as it relates to the context of engineering technology in society
- demonstrate improved communication skills including written, oral, and multimedia
- conduct a patent search and write a patent disclosure for novel work
- utilise information obtained from sources that cross geopolitical and language barriers.

These are in line with the basic ABET 2000 requirements (section 3.2.1).

However a main component of the Clinics has been to prepare the students for more rigorous research in their third or fourth years (junior and senior years). The Clinics in these years offer the academic staff and students the opportunity to conduct applied or fundamental research - the research is mostly funded with collaborations and industrial partnerships, from regional industry to international projects with universities and business. Examples quoted by the authors include (a) a technology demonstration project with the US Air Force on biogeochemical reductive dechlorination involving teams of civil, environmental, chemical and mechanical engineering students, and (b) an international project with universities and small business in Chile to develop and optimise aquaculture processes. In order to prepare for this type of multi-disciplinary research and/or design project, the Engineering Clinics in the first and second years develop the necessary skills.

The Freshman (first year) Clinic is a multidisciplinary Introduction to Engineering course consisting of a one-hour class and a three-hour laboratory each week. The activities are designed to introduce the students to the practice and profession of engineering through teamwork, problem solving, the design process, safety, professionalism and ethics. This also comprises the development of technical communication skills, time management, studying and test-taking. Example projects are based on two themes: (a) laboratory modules on engineering measurements from all disciplines applied to food-processing, carbon nanotubes, fluidised beds, and sustainability among others, and (b) design through reverse engineering and competitive assessment of consumer products such as electric toothbrushes, soccer helmets, beer brewing and blood pressure cuffs, among others.

The Sophomore (second year) Clinic focuses on introducing the students to open-ended design problems. Students are separated into two groups: one culminating in construction and testing, the other in a paper design or evaluation. Example projects include crane design (again multidisciplinary, including aspects such as the environment and product lifecycle) and assisting in Rowan University's commitment to reducing greenhouse gases which involves final and mid-term presentations and progress reports to the university facilities personnel and academic staff (which has indeed resulted in a change to university practice).

4.3 Learning through case studies

4.3.1. Snapshot: Digital Studio Technology

This snapshot describes a module called Digital Studio Technology (ENGE384), delivered at level 3 of the BSc (Hons) Audio Technology with Multimedia and the BSc (Hons) Audio Technology with Electronics courses. It is a 20 credit module. Approximately 60 to 80 students, divided into laboratory groups of up to 20 students, take the module as part of their course. The module is primarily based on group work and there is an emphasis on self-led learning: the students work in groups of between three and five students to carry out their coursework. The module is delivered by three staff members.

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Description of the course or module

The module involves student case study coursework based on research conducted in the university as part of a project called Emotion Classification in Contemporary Music (ECCM, 2009). The aim of the module is to enable students to understand the methodology and principles of digital audio processing and recording that are used in modern recording studios. Students are expected to do objective and subjective assessment of audio signal quality, understand digital audio theory, and use digital audio workstations. The group coursework requires that a formal subjective listening test is designed and carried out. This ranges from statement of hypotheses, recruitment of listening test subjects, planning experimental design, preparation of test materials, and statistical analysis of test results. The course incorporates extensive use of online learning environments (Blackboard): students had access to an online forum which allow them to recruit fellow students for their group coursework activities. Finally, the results must be presented during a formal group oral presentation.

Links between teaching and research

These activities involve the students in the development of a range of research skills through direct exposure to, and involvement in, academic research. The coursework is based on research carried out by the module leader.

Student assessment:

Assessment is based on two summative coursework elements (20 per cent and 30 per cent of final grade respectively), and one formal written exam (50per cent of final grade). Students receive marking schemes with the coursework documents. Feedback on performance is provided after completion of the coursework, and also during the oral presentation.

Effect on student experience

Students seem to benefit from the activities in this module. Informal and formal feedback suggests that students enjoy the listening test group coursework. Students learn how to design and carry out a formal scientific experiment, to analyse test data, and to plan a large project. Students also learn to work together in a group, which includes assigning group tasks, and managing time. Students also formally present their work in an oral presentation; this builds their confidence.

4.3.2. Case study: Urban Design 1

This case study describes a fourth-year module, Urban Design 1, taken as part of the architecture degree course. It is (at the time of writing) an optional core module within the honours year Architectural Studies worth 20 credits. Currently, 18 students take the class, taught together in one group. The class is becoming compulsory and will then increase to between 30 and 40 students (this might lead to two student groups being formed for the delivery of the module). The class is delivered by one lecturer, supported by guest lecturers from practicing urban designers.

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Description of the module

This class introduces students to concepts of urban design and represents the students' first formal course in this subject. The focus of the module is what urban design means for architects and the other professional disciplines that contribute to urban design. There is particular emphasis on social sciences and environmental psychology. The module is taken in an academic year directly preceding a year in architectural practice where they will gain experience with professionals from other built environment sectors.

Half of the module is delivered through formal lectures from the class lecturer; a further 20 per cent of classes are given by the guest speakers providing a good balance of the practice-based perspective. The guest lecturers provided by the practitioners provide an overview of the role of urban designers; and allow discussion on how theory can be applied. A psychologist also discusses how spaces are perceived from the user's point of view rather than the designer's point of view. Presentations also cover assessment techniques, or ways of evaluating how space performs. The lecturer for this course is on the Glasgow Urban Design Panel, and the content of this class is linked to the work of the panel in the form of case studies. The panel, made up of experts from many organisations, meets once a month to give views, opinions and recommendations on projects proposed for Glasgow. Current issues facing the panel are incorporated in class; for example, the class discusses the merits of proposals for development on the Clyde. Master plans cannot be shared with students, but students can comment on the themes. A practitioner may discuss their views and review mistakes that they think have happened in Glasgow, and then students propose solutions. Issues of walkability and commutability are discussed in class. The final 30 per cent of the module is devoted to student-led seminars: students are provided with readings that they have to present to the class.

Links between teaching and research

This case study is a good example of the linkage between research (in the sense adopted by this Enhancement Theme) and practice-based design issues, as discussed in section 3.4.1. As noted by Roberts (2007), the module uses a student-centred approach and the research undertaken by the students (that is, case studies and readings) is a means of developing other learning outcomes. Students present seminars in the same format as a conference; two students present a reading and one student chairs. Every student is graded on how they contribute to the discussions that follow the presentation. The students have a valuable opportunity to learn from both an academic doing research and real practice-based design/research presented within the lecture series. In this case, the Lecturer publishes on urban design (and is part of an alliance called Urban Sustainability through Urban Design) and does research on community involvement and design, which is incorporated in the class material.

Student assessment

Grade is assigned as 20 per cent for a student's contribution to discussion after presentations, 40 per cent for an essay and 40 per cent for the presentation of assigned reading.

Effect on student experience

The student's experience seems positive: discussions were so interesting students continued beyond the allotted class time. Essays are well written, and it can be seen that students became critical thinkers with respect to architecture. Students understood that they have to incorporate knowledge from other disciplines, and in this class students had to use different sources of evidence to substantiate their arguments. The students come to learn the skills associated with a practising urban designer who needs to network, manage, and relate different types of information, and can find information in many different places. An urban designer understands how things work in relation to each other and that design is only one part of the built environment. Thanks to the quality of student work in this class the lecturer secured financial support from city council to publish student work every year.

4.3.3 Case study: Cultural identity

This case study describes a third year module delivered within the architecture programme for the BSc in architecture. The module takes place at the start of the year; it is worth 15 credits and takes three weeks to complete. There are about 20 students in the class. Four people are involved in teaching this module: an assistant lecturer from Texas, who is the Chair of Design at the University of North Texas, the Course Director of Interior and Environmental Design at Jordanstone College of Art and Design, a workshop technician for constructing objects, and finally a CAD specialist.

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Description of the module

Students initially work together in small groups and then separate to work remotely with partners on independent projects - each have a partner with an interior design student at the University of North Texas. Scottish-based students are randomly matched with their US peers, they never meet in person, instead communicating through email, text messaging, and finally in a video conference.

The goal is for each student to design a project brief and create a three-dimensional cultural artefact that embodies and illustrates the cultural identity of their partner.

The brief sets the parameters, identifies a context and underlines the relevance of a student's design; it has a loose framework which students are encouraged to interpret. Students are given rules of engagement which dictate what can and cannot happen in the project. Each student 'method' designs (like method acting) - this is similar to the work of IDEO, a Global Design Consultancy (IDEO, 2009): with their partner, each student alternates between the roles of a 'proxy designer' and a 'pseudo client'. A successful 3D artefact design requires thoughtful communication with a partner who has a different cultural background, and interpretation of the partner's words, communicated through text. The project allows students to explore the crucial role language plays within the visual; as a starting point, students design written questions for their partners, not spaces. Students direct questions at each other, and use the responses as the source material. In communicating with their partner, students use written language, communicating through email and instant messenger. The goal is to improve student communication skills. Students need to learn to read signals or read between the lines of what their pseudo client actually says; they need to interpret what their pseudo client wants just as designers rely on interpretive skills. Most students already use technology to communicate socially, but when communicating as professionals, they need to be more thoughtful about what they say in these mediums. Students should distinguish between how they chat to their social group, and how they must professionally communicate about their work. The project allows students to experience how designers and clients interact. Students discover how that relationship can be fraught with difficulty and tension. Among other communication challenges, the client-designer partners must negotiate a six-hour time difference. The project culminates in a one-day video conference, in which each student presents the three dimensional cultural artefact they have designed to their pseudo client. Ultimately, this creation of the 3D cultural artefact challenges the industry's approach to things like mood boards, and suggests alternatives to the way creation is done in industry.

An important objective is to allow students to challenge their cultural assumptions, and develop empathy. Students must explore their pseudo client's cultural identity. Beyond clichés, students need to determine what could be used to define Scottish-ness and American-ness. These activities prepare students to work in a global context, and reveal the international student body in Scottish universities. A fundamental part of the project is to discuss how design schools around the world, such as Delft and Stanford, explore ideas of cultural identity through design. Students also explore the cultural dimension of design in the twenty-first century in workshops with the previous cohort of students.

Links between teaching and research

This case study also provides a good insight into design/research attributes. As well as developing design skills, students also develop skills that will be useful in doing research. They acquire a range of communication skills, analysis, interpretation, a facility in reviewing the field of enquiry, and thinking about how industry works, and they see how other researchers in other international design institutions are following similar paths. Students learn about current research by reading some technical papers at the beginning of the process. Students also participate in international design workshops that involve Dutch, Swedish, other US, Chinese, and Korean design students. As an international digital project, students have a great deal of independence and autonomy. Students have to be encouraged to take intellectual and creative ownership of their projects, and the school has to relinquish control - see also (Milligan and Mohr, 2008). Students develop analytical and interpretive skills and are expected to trace their actions and judgements and to link a body of evidence to their own creativity. They have to reference other peoples' ideas and how those ideas have affected their own work. Finally, they also have to demonstrate intellectual depth in the design process, and relate their own response to the project while demonstrating an understanding of how designers around the world are working collaboratively, co-designing, and thinking about the cultural dimension of design.

Student assessment

The outcome of the project is the creation of a three-dimensional cultural artefact, which in some ways seeks to embody and illustrate the cultural identity of a US student. There is ongoing formative assessment, in which academic staff (Scottish students meet only with local staff) try to guide students as they overcome problems. Students give presentations in the video-conference on the final day, which is videotaped - these presentations are part of their final assessment and all students from both institutions participate collectively. The instructor reviews the quality of the final constructed artefact, the professionalism of the presentation and the consistency of effort throughout the project. Students are interviewed and appraised on set criteria: presentation skills, visual and verbal articulation, creativity of their solution, and time management. Students are expected to demonstrate an understanding of design research, analysis, selection and development, and subject awareness and an understanding of subject-specific skills and practice.

Students also self-assess, assessing themselves and their Texan partner. Students create this self-assessment using a scoring/feedback sheet, in which they rate a number of factors such as their level of involvement, the related tutorials (workshops, meeting with peers), tutorial guidance, the number of projects, suitability or relevance of the projects, overall value of the module, and students have the opportunity to write out their own comments. Students are given a speculative grade by staff which the students and lecturer discuss before the final grade is awarded. Students may defend their work and provide an argument for a higher grade.

Course evaluation

The Higher Education Academy has supported this course as a case study. Discussions of this course have been accepted at international conferences as well. (Shaping the Future conference, Engineering and Product design conference 2007, and the Higher Education Academy/CEBE the IDEC Reason for Being conference in Montreal.)

Effect on student experience

Students learn to overcome many challenges to complete this project. Although there is a frame work provided through the original project briefs, students very quickly realise that they have to navigate a way to communicate with their pseudo client (made difficult by the time difference). This class is the first time students recognise that others are working the same area of culture. Students are reassured by learning about other people in the field, and they are extremely excited about their virtual meeting with their Texan counterparts at the culmination of the project. Students completely underestimate how hard it is to structure and design questions, and they are given a very healthy counterpoint to the ways that text affects their learning - they need to think about communicating through text and verbally. Most students don't like writing, but they have to learn to deal with it: this project should then help students embrace textual communication so that text becomes a dynamic part of their design skills.

4.4 Internships and placements

4.4.1 International exemplar: Lafayette College, USA - EXCEL scholars programme for undergraduate research

Engineering, third and fourth year students

Source: Jemison W D, Hornfeck W A and Schaffer J P (2001) *The Role of Undergraduate Research in Engineering Education*, ASEE Annual Conference & Exposition, Albuquerque, USA, session 3630

Lafayette College is a small (2,000 students and 200 academic staff), independent residential college with around 20 per cent in the Engineering Division (chemical, civil, electrical and computer and mechanical engineering). The college does not grant doctorates, but ranks first in the USA in the number of engineering students who go on to complete a PhD. The EXCEL programme was designed to make the prospect of postgraduate work for student engineers more attractive and maintain its strong record in graduate school placement. The programme annually supports around 100 students in high quality undergraduate research projects funded from external research grants, private foundation grants, endowments and the college. Around 20 per cent of engineering students and 50 per cent of academic staff are involved in the programme.

The programme is open to all students with good grades (a GPA of at least 3.0/4.0) and is particularly popular amongst engineering students. It is the student's responsibility to find a suitable research partnership with a member of academic staff, although the latter may initiate the partnership. The academic staff member then prepares a proposal for the Faculty Academic Research Committee who then review it. Each proposal presents the student's research topic and a case for funding, principally including financial support for work in the summer months (a student can earn $7,500 this way). The funding is typically for one summer placement but the team can re-apply in subsequent years. Within the Engineering Division, typical student responsibilities include: literature searches and reviews, equipment design and construction, experimental design, data gathering and analysis, contributions to theory and/or model development and the preparation of parts of publications.

Many EXCEL scholars have presented their work at the National Conference for Undergraduate Research and a (select) few have published papers with their academic supervisors in professional refereed journals. Of the 23 scholars mentored by the authors, 15 have gone on to graduate school in top research institutions (Georgia Tech, Lehigh, MIT, Stanford, UC Berkeley and Cornell).

4.4.2 International exemplar: University of Maryland Eastern Shore, USA-Complete Research Cycle

Engineering and Technology, third and fourth year students

Source: Johnson R A, Mack K M and Seaton D M (2005) Developing a Complete Research Cycle (CRC) in Science, Technology and Mathematics (STEM) in *CUR Quarterly*, volume 26, number 1, pp 28-33

The University of Maryland Eastern Shore (UMES) is a historically black college and campus of around 3,500 students, with around 400 in engineering and aviation sciences and technology. It has implemented the Complete Research Cycle (CRC) programme to stimulate undergraduate research, with funding from the US Department of Education and the National Science Foundation. The motivation for introducing the CRC programme was not only to increase student interest in STEM subjects, but also to improve progression rates of minority students, particularly through multi-disciplinary group work. The programme is designed not only to give third and fourth year students the opportunity to work with academic staff on 'real' research projects but also to expose students to current trends and practices in their disciplines. The CRC emphasises the development and maintenance of an interest in research, inquiry based activities, formulation of research proposals and activities, investigation and reporting replicating the common features of sponsored research, rather than simply a short period of internship or placement during the summer months within a research group, or working with a member of academic staff.

To simulate a sponsored research environment a request for proposals is issued to academic staff and students (generally third and fourth years (junior and senior students) but proposals can include freshmen and sophomores). The programme offers $6,000-$10,000 per project (average $3,500 stipend for the staff member, $2,500 stipend for the student and $3,000 for supplies and travel allowance). Students must be actively involved in the proposal preparation, which is then submitted to a review board. Once the proposal is awarded, most research projects take place during the summer, but can be extended through the academic year. Students are required to work to project plans, together with the academic staff or independently, depending on the project. Following the project, typically during the next winter break, the students have the opportunity to attend national or regional conferences to report their results as well as a UMES research exposition and retreat. The students are exposed to many aspects of conference participation, including travel planning and authorisation, preparation of presentations, attendance at plenary sessions and so on. The final part of the CRC is the preparation of the results for publication, again usually done during the following academic year. Students submit papers to an UMES undergraduate research journal, which includes all aspects of the peer review process: submission, an editorial/review board with nationally recognised experts, and so on. Articles are not rejected, but subject to a revision and resubmission process.

4.5 Project skills preparation, learning what research is

4.5.1. Snapshot: Research skills in design philosophy

This snapshot describes a design philosophy module for third-year architectural students. This module, worth 15 credits, consists of around 45 students. Students work together in groups of five or six to present seminars. There are three lecturers involved in teaching this module, being specialists in design theory, social science, and urban design.

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Description of the module

This module covers urban design topics and presentation and research skills; it is taught as one group using lectures and student-led seminars. The lectures focus on key research areas in urban design. Each group of students is required to give a 15 minute presentation on a topic that has been assigned to them. Students are encouraged to find information for their seminars in journals and case studies and to synthesise that information in a written report as well as the formal presentation.

Links between teaching and research

The lecturers are teaching about topics that are close to their own research; topics they are passionate about. Students are engaged in literature searches as a fundamental part of this module. They develop research skills as they search and evaluate information and through this are exposed to current research in this area. The parallel lecture series provides a large range of current research directly to the students. There is no conscious effort to monitor the pedagogical outcomes (acquisition of attributes) but peer-teaching and peer learning do happen in this module. The module has two aims: the first aim is to raise students' awareness of the wealth of information available to them if they familiarise themselves with the method of finding information and the ability to find information in the published research which will benefit their education and graduate career. Students need to learn to reference where their ideas come from, and develop their ideas using evidence. Students own writing and thinking should become clearer as the result of synthesising information from different sources. The second aim is to help students communicate ideas more clearly and convincingly.

Student assessment

The students have to sit an examination on design theory, give a presentation and write an essay using a mixture of group and individual assessment.

Course evaluation

The whole course is continually reviewed and validated (people from two other universities and one from practice validated the course).

Effect on student experience

All students develop an appreciation for urban design and why the design of public space is important; the principles of urban design give students a context for every building that they encounter. Students understand the wider context for their own design work, and the importance of a building's design to the people who use the building.

4.5.2. Case study: Advanced Design Studies

Advanced Design Studies is taken by master's level engineering students in civil engineering. Around 15 students take the class, which is delivered by the class instructors and subject specialists. The course lasts for three terms.

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Discipline area: civil engineering

Description of the course

This course has been taught with the current structure for six years. The course developer, and principal instructor, came from industry and felt that design, communication and team work skills were missing from the degree at that time. Goals for this particular course include high level technical design skills and experience of working as part of a team in a design environment. The course begins with four or five lectures on technical issues that the students have not yet encountered in their degree programme. Thereafter, the students work together in groups on an integrated design project. Fifteen students typically take the course, and they self-select into three groups of five students. All groups are assigned the same project, and though each student in a group completes a different task, the group have to work together to create an integrated, functional design. The project is designed so that the result from one student's completed technical calculations is the starting point for another student's assignment, so information must be transferred accurately from one student to the next. Students need to communicate clearly in order to complete the combined tasks successfully; communication is emphasised because it is in the transfer of information between parties that civil engineering project teams often make mistakes. Oral, written and graphical communication skills are emphasised.

The goal of the course is to give students experience of working on a real-world design project while still in an academic environment; however, the real world is so complex the most difficult factor in the continuing development of the course is to simplify the project to something which students can handle in the time available. The key to developing this type of teaching is to simplify problems to something manageable.

In addition to the assigned teaching staff, subject specialists are usually brought in. For example, when a group design a flood defence scheme, specialists with experience in designing reinforced concrete walls and earth embankments, or managing data from GIS (geographical information systems) contribute to the course. Students are expected to integrate knowledge from different courses, such as Geotechnics and Hydraulic Design, in their designs. The principal instructor is always looking for new ideas, and has brainstorming sessions with local industry representatives for new design projects. A civil engineering advisory panel made up of people from industry also suggests projects. As a result, the course design exercise is refreshed about every four years. Content that connects to the outside world makes the course more interesting for students. This course therefore connects to the real world in two ways: the manner in which students work together connects to their career after graduation, while the design topic they study connects to issues that the Scottish Government thinks is important and it provides funding.

Links between teaching and research

The students are mainly exposed to advanced design skills as well as the required professional engineering attributes connected to problem solving, teamwork and communication skills. Students also learn about current research in this area: the lecturer's research is in computer flood modelling, and students are exposed to the state of the art in this particular area. Students learn about more advanced flood modelling than they would typically use in industry - problems with commonly used models used in industry are highlighted, together with the need for models in industry to be continually being updated and improved.

Student assessment

Each student will submit a package of technical calculations for the final group report. The best students would characteristically extend the calculations beyond what they have learned in classes (for example, they may justify that a wall will stay up given a certain level of flood). Although they work together in a group, each student's individual contribution must be identified and assessed separately. Each group submits a comprehensive written report, with separate sections completed by each student; it concludes with a recommendation for the client on the best solution. The different sections of the report must be consistent, indicating accurate information transferred between group members; communication skills are assessed separately in twice-monthly meetings with the instructor. Maps and sketches in the report are used to gauge students' graphical skills. In addition, each group gives a final presentation, which should be accessible to specialists as well as any other educated person, on their project.

Effect on student experience

The course is designed to give the students a realistic experience of an advanced design project in a teamworking environment - the skills which are developed are directly applicable when the students graduate and start work in civil engineering. The instructor aims to make the students able to look at their own work and critically reflect on it, to begin to learn how to teach themselves and to give them increased confidence in their own ability to solve problems as part of a team. For their part, the students find this course interesting because they realise that in several months this type of activity could be their responsibility in work.

4.5.3 International exemplar: LeTourneau University, USA - Undergraduate Student Research Laboratory

Engineering, third and fourth-year students
Source: Gonzalez R V, Lopez J and Leiffer P (2004) *Is a successful research laboratory possible with undergraduate students alone?* ASEE Annual Conference & Exposition, Salt Lake City, USA

This exemplar suggests an answer to an interesting proposition: is it possible to run an engineering research laboratory with undergraduate students **alone**?

LeTourneau University is a Christian college of nearly 4,000 students. Academic majors include the aeronautical sciences, engineering and engineering technology. It does not have a graduate programme in these disciplines. Most research projects are in biomedical engineering: at the time of publication, the group were running two multi-year undergraduate research projects, one on intelligent prosthetic arms, the second on aspects of bio-mechanics in an injured knee. Although undertaken within biomedical engineering, the projects are multi-disciplinary.

All final-year students must have a 'capstone' project, which can involve working in the undergraduate student research laboratory or a design team. Third-year students who intended to join the research laboratory have the option to participate as a 'junior' member of the senior (fourth year) research team for three hours per week.

(In fact, for biomedical engineering majors this is compulsory). This allows a two-year research involvement for the students. The teams are multi-disciplinary with members from biomedical, electrical and mechanical disciplines. The fourth-year involvement includes design and development as well as research. The students are also prepared for this involvement through earlier courses on design, teamwork, report-writing and presentation skills.

Teams in the research laboratory can be up to 25 students, managed through a team leader-structure with the academic research adviser as principal investigator together with several fourth-year student team leaders who are instructed in mentoring. The team leaders then mentor their subgroups on the tasks required, including third year students who 'learn the ropes' in preparation for a fourth year as potential future team leaders. This constant mentoring process is seen as vital to success. A particular research project then has a management structure comprising project manager, engineering leads and individual contributors roles assigned to students under the academic Principal Investigator who guides the project (and has the important role to motivate the students). The Project Team, under the Project Manager are required to produce project plans (Gantt charts), full project documentation and ensure a quality assessment procedure.

Has this been successful? At the time of writing, over $700,000 of federally-funded projects had been secured, involving over 100 undergraduate students over eight years, performing research during their third and fourth years. Over 30 publications have appeared in peer-reviewed conferences, with over 15 students electing to pursue doctoral work at various leading graduate schools.

4.5.4 International exemplar: University of Queensland, Australia - linking engineering management and research

Mechanical engineering - third-year students

Source: Radcliffe D F and Humphries J (2004) *Making the Link between Engineering Management and Undergraduate Research*, ASEE Annual Conference & Exposition, Salt Lake City, USA

The University of Queensland developed an innovative engineering management course that uses a project management framework applied to a feasibility study for a prospective final-year research project.

The course was developed to replace 'traditional' engineering management courses, which were felt by academic staff and students to be more relevant to large organisations and to engineers in mid-career. A new style of the course in engineering management and communication was developed. It is a compulsory course for all third-year students in mechanical engineering. The objective was to have the students experience engineering management principles in the form of project management in a team, while also reflecting upon the experience. The innovative aspect of this course was to have the students undertake a feasibility study that defines and plans for the final-year research project. The course addresses the need to provide explicit instruction on conducting research, but in a creative way, which uses management techniques to guide and foster research and critical analysis skills in order to (a) identify and formulate engineering problems in a research or design context and (b) to plan and control a prospective project. To achieve this, third-year students work in teams on a prospective project in a way which replicates project management: definition, planning, execution and handover. The deliverable is a project plan. In the subsequent year, one or more students (not necessarily from the group who conducted to relevant feasibility study) undertake the project, commencing with the plan drawn up by the team in the third year.

The learning objectives of the course are to be able to critically analyse the context of a prospective project; scope a project; select appropriate methods; estimate project resources; manage project risk; plan, monitor and control a project; document thoroughly; and present effectively. The students work in teams of five or six to conduct a feasibility study for a prospective research project. The study explores the literature and related issues to formulate the problem in consultation with academic staff. It involves further consultation with academic supervisors (acting as the 'client') and the presentation of a series of reports (two interim and one final) at approximately four-week intervals. Each involves an oral presentation. The first report is the Context Report which should provide a comprehensive analysis of the proposed project including all stakeholders, a critical summary of prior-art, a list of constraints and risks and a summary of the objectives of the project and key performance indicators (KPI). The next Definition Report should define what is to be done, why and how and what resources it will require. The project should be fully scoped and have an updated set of objectives and KPIs, discuss duration, estimate the budget, outline the approach to be taken and methodology, list deliverables and include a risk assessment and value management exercise. The final report is the Project Plan: it must include a project schedule, a quality a management plan, a risk management plan, a communications plan, a procurement plan, a performance management plan and a documentation management plan. It must also include a critical analysis of the operation, monitoring and control of the team project at the end.

The course covers additional materials such as the nature of engineering projects, the process of project management, financial accounting, library research through workshops and recommended reading.

Radcliffe and Humphries concluded that this approach has the potential to benefit both students and academic staff. Students gain relevant professional engineering skills plus real competencies, which can be applied in final year research projects. Academics benefit by having students better prepared to undertake their research project.

4.6 Individual research project

4.6.1. Snapshot: Flood risk management

This snapshot describes a one-year postgraduate course leading to an MSc. qualification in Sustainable River Catchment Flood Management. The module is worth 15 credits. About 20 students take the course, which is taught by a team of seven staff, who range from new lecturers to senior lecturers - occasionally doctoral students also contribute.

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Brief description of the course

This course covers flood risk management, from coastal, river or sewage systems. The course is delivered in a standard lecture and tutorial format, with an emphasis on computer simulations for modelling flood flow; it includes a limited amount of field work, site visits and guest lecturers given by practitioners. Students spend one third of this course studying for their research dissertations. Students submit their own work, but they are encouraged to research topics together, giving them opportunities for peer-to-peer teaching and learning. The teaching staff, communicate with students individually two to three times per week.

Links between teaching and research

The links are direct and explicit by design. During the lecture series students learn about current research - exposing students to the forefront of science in the field. Students studying this course are expected to directly develop skills that will be useful in doing research when carrying out their dissertations. As a result of their dissertation work in this course, masters students often become authors on papers, which is very valuable in their careers. Last year, of the twenty students completing the course, three carried on to doctoral work directly related to the project initiated in their dissertation.

Student assessment

One third of a student's grade is based on traditional examinations. One third is based on course work. Coursework makes use of a number of educational approaches including solving analytical problems, writing essays, and using computer programs. The remaining assessment is through the student's research dissertation. The dissertation work is presented to the class, academics and industry representatives.

Course evaluation

The main review process for this course is the Institution of Civil Engineers, who do a detailed review every four years. This Institution has criteria for technical content, writing, research, and presentation skills. Employers give feedback based on presentations; roughly 40 per cent of presentations are done with industry contact, where students meet weekly with an industry representative. Feedback from practitioners is very important: two or three times a year the academics and practitioners meet to discuss changes to the course, for example, having students familiar with the latest software packages. The same employers recruit students from the course every year, which is a sign they trust and value students from this program.

Effect on student experience

The academics teaching this course are active at the forefront of research in this field; there is a critical mass of staff in the department with strong research programmes. Having staff with such breadth and depth of knowledge makes the course very robust and has a positive effect on the students' experience of research following guided instruction.

4.6.2 International exemplar: University of South Carolina, USA - Engineering Research Communications Studio

Chemical/electrical/mechanical engineering - final year students

Source: Thomson NS et al (2004) Integrating Undergraduate Research into Engineering: A Communications Approach to Holistic Education, *Journal of Engineering Education*, volume 94, number 3, pp 297-307

The importance of communication skills in the professional formation of engineers is well known, and can be seen in the UK-SPEC, ABET and most other requirements of professional bodies (section 3). Indeed, numerous academic, professional and employer surveys have ranked 'communication' as among the top ten skills required in the engineering profession. As a result, there are numerous examples of professional skills development courses, or opportunities to practice, to be found in almost all engineering and built environment degree courses. Nevertheless, it has been recognised that high quality instruction in communications skills must be provided not only by engineering academics, but also by communication experts, and that the instruction should be individualised. These features have been the basis for the Research Communications Studio (RCS) at the University of North Carolina. The Studio is a structured approach for teaching students authentic written, oral and graphical communication tasks required by research, while they are learning to do research.

The main activity of the RCS model consists of weekly one hour group meetings of RCS staff with small groups of undergraduate students from chemical, electrical and mechanical engineering - a cross-disciplinary group. The staff members serve as group leaders and include a postgraduate student mentor, a communications research assistant and a communications faculty member. The meetings focus on individual student's research project work in progress. Each student tells all the group members what specific help they need, followed by a discussion. The group leaders model and teach group procedures for providing positive feedback and suggesting how communication could be improved. During the meetings, the students practice informal talk about their research, give PowerPoint and poster presentations; each member reads drafts of progress reports, pieces of writing for publication and any other assignments given by their academic supervisors - students can also bring graduate school applications. All students produce a task plan which outlines research objectives and deliverables. Other assignments include progress reports, documentation, user manuals, posters, conference papers, journal articles, and so on.

Both staff and students were surveyed and a high level of satisfaction was reported. Academic staff, acting as research project supervisors, reported that their students better prepared for research and design - as well as being better prepared for audience needs when they have to communicate. The participating undergraduate students were also highly satisfied by the experience.

4.7 Group research project

4.7.1. Case study: Group design project

This case study describes an honours year module worth 20 credits. It is taken by students studying mechanical and chemical engineering. The module is based around a group design project. About 60 students take the class, which is project based; students work together in groups of five to six students. The teaching is led by one research-active lecturer, with assistance from other members of academic staff and a visiting industrial lecturer.

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Description of the module

The goal of the module is for students to integrate different disciplines in a single project, to work together as part of a group, and to be able to work independently. The technical goal is to design a micro-system that detects chemicals in a fluid. This requires integrating electronic, mechanical and chemical engineering.

An introductory lecture sets guidelines for the module, and there are a few follow-up lectures. There is an essential external, industrial influence for this particular course: a visiting lecturer from industry is involved in the module. Their role is to set out the expectations for the systems students will design. Other than this, students work in groups and meet together on their own, setting their own meeting times. Groups are mixed to contain students from all disciplines; they are required to allocate a group leader and assign specific tasks to each member. Group members must set goals for themselves and report back to the group to re-evaluate and set new goals. This structure is meant to be a realistic scenario for people who will work in a research laboratory at a university or in industry. Students meet with an instructor every two to three weeks to check on progress and for realignment as necessary.

Links between teaching and research

Instructors put together projects that may not be identical to real-world scenarios but reflect real-world processes and procedures. The instructors are active researchers who have built the course around their own research interests; this makes them much more excited about teaching. Students benefit through greater insight into the research methodology: they learn that results have to be validated and verified, then published, disseminated and reviewed by peers. Students are questioned quite closely in defending their thesis, and often then discover they haven't asked as many questions during the project as they should have. Students are encouraged to reflect upon what they have done and how they could have done it better. Students benefit through exposure to this method of working, using a variety of methods to determine whether their results, as far as can be understood, are correct. Effectively, students are working in a way that is similar to a doctoral student, and they get genuine insight into a group's research.

Student assessment

Students present a technical design including diagrams and calculations and an overview of what their device does together with a technical specification of how it will be manufactured. This includes electrical schematics of how the design works and a cost for manufacture of 10,000 or 100,00 units. Key points include the technical data, what impurities their device would be able to detect, and at what sensitivity. There is a final technical paper presentation and an oral group presentation to the industrialist. Groups decide how their report will be brought together; however, most groups prefer each student to write up their own work and then one student integrates all the results. The design and final report is the product of a group, but each student is assessed individually for their contribution and effort.

Course evaluation

Evaluation is fairly standard for this type of course. An internal review group meets every two to three years to provide more formal feedback; this review group is made up of staff in the department. An industrial liaison board reviews the entire programme, but doesn't become involved in details of individual courses. An education board at the university, and the IET (the Institute of Engineering in Technology, which formally accredits the course for chartered engineers status) both review the course.

Effect on student experience

This class is an excellent experience for the students as they have the opportunity to integrate technical information from different sources and see how that information contributes to a specific product. When engineers develop a product, they cannot rely only on topics covered in their degree course - instead, a range of issues must be considered. In this course, students are similarly exposed to advanced concepts that go beyond what they've been directly taught in lectures. Students must consider the feasibility of their designs and are stretched beyond what they thought they could achieve. Some students develop a great deal of enthusiasm for a subject they have researched. One challenge for students in this type of course is to figure out potential areas of specialisation for themselves on graduation: are they suited to analogue design, embedded systems, software-engineering, designing microelectronic devices, communications, mobile phones, or networks and so on? For some students, doing a research project helps them discover where their interest lies.

4.7.2. Snapshot: Environmental assessment

This snapshot describes a level 2 environmental design module taken as part of an architecture degree programme. Approximately 60 students take the class, working in groups of four students. This class is taught by one full-time lecturer and one part-time lecturer (studio teacher).

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Discipline area: architecture

Description of the course

Students develop their ability to evaluate the environmental design performance of a simple building structure using a basic environmental assessment computer model. Students are expected to: understand how to use an environmental evaluation model, how to analyse work using these computer simulations, how to carry out simple comparative analyses, how to present work individually and in groups (verbally and in written reports) and how to use a virtual learning environment (Moodle) for learning and communication.

Links between teaching and research

During the course of the module, students develop skills that would be useful in carrying out research, such as team working, individual analyses reinforced by group analyses, presentation work, and report writing incorporating critical analysis of research. Students learn about the use of computer modelling in environmental analysis, which is an active research area in itself: the model used in this course is continually being upgraded and further developed, and student feedback on the model is sent back to the model developers at Cambridge University.

Student assessment

Students are expected to deliver at the end of the course: (a) a group presentation of the results of evaluating their designs using the environmental assessment computer model, (b) a group report explaining how the results in their presentation were achieved, and (c) a self reflective report discussing how the project contributed to the individual student's learning experience and understanding of environmental assessment through the use of computer modelling. Assessment is formative: feedback is given at tutorials and during the group presentation - at the end of the project, tutors gave feedback on all the learning outcomes.

Effect on student experience

Students seem to benefit from the course. Some students go on to use the modelling programme for their environmental design work in the third year. Also, the information is placed in the reflective portfolio, which comprises part of the ARB Part One requirements for qualification as an architect.

4.7.3 International exemplar: University of Canterbury, NZ - compulsory research project with cultural engagement

Civil and natural resources engineering - final-year students

Source: O'Sullivan, A and Cochrane, T (2009) *Preparing Better Engineers: Compulsory Undergraduate Research Projects that Benefit Universities and the Profession*, ASEE Annual Conference & Exposition, Austin, USA, paper AC 2009-424

The University of Canterbury offers a fairly unique degree in natural resources, which is accredited by the Institution of Professional Engineers, New Zealand. It includes aspects of biosystems and bioresources combined with ecological and agricultural engineering. A focus of the degree is partnering with environmental protection agencies and local industry. A unique aspect of the degree is the inclusion of indigenous people's cultural engagement. In New Zealand, the Maori are the legally and culturally recognised guardians of the country's natural resources according to the Treaty of Waitangi. As a result, the students must be made aware of the importance of working with indigenous peoples for successful engineering outcomes.

Final-year students on the degree are all required to undertake a compulsory group research project. Projects are developed jointly by academic staff and industry practitioners and are based on some sustainable engineering problem with interdependencies between people, the environment and the economy embedded in technical solutions. Most projects are funded by industry partners, at little or no cost to the University. The project objectives are aimed at exposing the students to complex and real-world engineering challenges. The practical objectives are:

- develop detailed and quality assured methodology for conducting a rigorous (team-based) research project
- generate a detailed budget, timeline and project management strategy
- write and present a mini research proposal examined by programme academics
- generate, collate and critique data for a defined problem. Perform necessary statistical analyses/modelling
- design a sustainable solution for the defined problem incorporating triple-bottom line considerations (integrated ecological, economic and cultural facets)
- produce sound conclusions and a substantial literature review
- deliver final technical report, oral presentation and attractive poster.

Groups of two students prepare five-page proposals containing most of the features of standard research proposals: aims, milestones, resources, timetable and outcomes. Each group must present the proposal orally to academic staff and the detailed plan agreed. The groups each have two academic supervisors who they must meet regularly; external mentors can also be used.

Students attend a compulsory two-day workshop, run by an outside organisation, to learn the principles and implications of the Waitangi Treaty in addition to workshops on library skills, written and oral communication skills, graphical presentation skills and a workshop on preparation of the grant proposal and budget issues.

One outcome of the compulsory research project for final-year undergraduate students has been a greater willingness to undertake postgraduate study.

5 Discussion and recommendations

The Scottish case studies (and snapshots), and international exemplars, reveal a broad range of approaches to the implementation of research-teaching linkages across the disciplines and in every year of study. Most of the Scottish case studies (taken from the Hadfield and Carter survey) demonstrate action which has been taken at the individual level for a particular class or module, although some, such as the University of Strathclyde mechanical engineering problem-based learning; the University of Abertay Dundee civil engineering foundation research skills; and Robert Gordon University architecture research skills in design philosophy, show a more strategic approach to introduce research skills and enquiry-led learning into the curriculum. Most of the international exemplars were chosen to illustrate more strategic approaches. However, it would be fair to say that the range of case studies and exemplars reported here would be familiar to most course directors and individual academics in engineering and the built environment as part of a typical degree programme, although they would not necessarily interpret their own department's activities as a deliberate effort to create the link between teaching and research - they would more likely recognise as the development of essential graduate attributes in their disciplines. There is the impression from this work that research-teaching linkages and the development of related graduate attributes are present in engineering and built environment courses, but are implicit rather than explicit - although some of this may be the presumption that the linkages are inherent. It may be argued that there simply needs to be a more conscious effort to bring to the surface the research linkages and graduate attributes which are present and explicitly make sure the students are aware of this. It may be further argued that the process of bringing these to the surface would not be time-consuming and could in fact allow new ideas and approaches to teaching to emerge, as well as unseen thematic links across a degree programme.

Much has been made in section 3 of the role of professional accreditation in these disciplines. Accreditation is based on the need to demonstrate the acquisition of student competencies (or 'attitudes' or 'attributes') throughout a degree programme, so it could be expected that the development of graduate attributes would not come as a surprise to academics in engineering and the built environment. The issue really relates to the development of those attributes associated with research and the student experience of an institution's research activity and environment. As mentioned in section 3, detailed research skills are not specially highlighted in most accreditation documentation - with the comment that there is probably the belief within the professional bodies that the linkages, and development of related attributes, would naturally take place. Although most accreditation requirements do not say much about research skills, part of the overall documentation submitted includes a detailed description of the department, its research activity and laboratory facilities. This Enhancement Theme has taken a wide view of the meaning of research (section 2.4) and it may be argued that the professional bodies have a similar, if also implicit, understanding. In engineering and the built environment in particular the synergy between research, design, consultancy or technology transfer is clearly evident. The case studies and exemplars indeed demonstrate the notion that these activities are present in most academic departments in these disciplines and that they are interchangeable. Indeed, the Hadfield and Carter survey asked the academic participants to submit good examples of research-teaching linkages, yet many relate to design. However, in section 3.2.3 it is argued that design and research are not the same, since they can lead to the development of different attributes. It is further argued that in the students' conception, they can interpret research as part of their individual and group projects (required for accreditation) in the final two years. Indeed many degree programmes (as reported in the case studies and exemplars) do include research skills preparation for these projects, and these projects can be based on the supervising academic's research interests (which could of course include design tasks, or consultancy or technology transfer with industry). Perhaps it may be better, from the student's perspective, to explicitly differentiate some of their learning activities as problem solving, design, project learning and research as suggested by Cordon et al (2007) - again, this would not be particularly time-consuming for any degree programme.

Without dwelling too much on the distinction between research, design, consultancy, and so on - since we are using a broad definition of research - in all of the Scottish case studies, academics were involved in research and research was embedded in the curriculum in some way - classes were research-oriented, led and tutored according to the Healey model, section 2.3. Participating academics in the Hadfield and Carter survey could readily recognise the place of their own teaching activity in the model, provided the broad definition of research was used. None of the case studies involved teachers and learners doing research together, except in the very common traditional relationship between supervisor and student in an individual or group project, but several were 'research-based', being examples of enquiry-based learning and design in particular. Following on the discussion from section 2.3, Trowler and Wareham (2007) expand the seven categories of the relationship between research and teaching (figure 3), such that the practices, benefits and possible dysfunctions of each are explored with the conclusion that there is no one approach that provides a perfect solution for linking research and teaching:

Meaning of the nexus	Practices	Suggested benefits	Possible dysfunctions
1 Learners do research	Research-based learning	Range of skills and concepts developed	Patchy coverage of curriculum
2 Teachers do research	Teaching cutting-edge material	Professionalises academic staff	Exclusion of students
3 Teachers and learners research together	Students as research assistants	Task-oriented and cooperative relationship	Learning too slow to cover curriculum
4 Research embedded in the curriculum	Research incorporated in curriculum design	Action research feeds into quality review and enhancement	Essential knowledge poorly effected
5 Research culture influences teaching and learning	Research culture permeates learning	Motivational context for teaching and learning	Research prioritised over teaching
6 The nexus, the university and its environment	Teaching and research are linked into the commercial environment and communities	Research-teaching links offer knowledge transfer and value in institutional reputation	The needs and priorities of employers and others take precedence
7 Teaching and learning influences research	Research projects refined and developed as with students	Mutual benefit to both teaching and research in a feedback loop	Substantive research becomes sidelined

Figure 3: the relationship between research and teaching (Trowler and Wareham)

From the case studies, the full range of the approaches identified in figure 3 can be found across the engineering and built environment sector in Scotland reflecting the diversity of educational approaches. If research in the Trowler and Wareham table is expanded to include design and consultancy/technology-transfer similar benefits and potential dysfunctions could be identified in many degree programmes, even those satisfying professional accreditation requirements, and most departments would do well to reflect upon this as part of possible course redesign. Specifically, the importance of individuals, course teams and departments should develop, and thereby own, their own conceptions of these issues - perhaps constructing a locally more relevant model:

> …it is quite possible that course teams may come up with different definitions of the four ways of engaging students in research and inquiry that are more appropriate for their context. The process of discussing and auditing their activities is where the value lies… (Healy and Jenkins, 2009)

Finally, two other aspects are relevant. The Hadfield and Carter case studies did not include the departmental/institutional perspective (in terms of strategy and culture), although Scottish academics reading case studies from their own institution should be able to put this in context. Also, the case studies did not obtain the participating students' perspective, although some focus groups were held for students in engineering in one institution to establish some ad hoc views (albeit for a single institution). Nevertheless, it is important for the reader to have some idea of these perspectives in a general sense - indeed, surveys and studies of departmental issues and impact on students available in the literature seem (so far) to be consistent among disciplines, even though there is (very) limited direct research evidence in engineering and the built environment.

5.1 Impact on students

Research on the impact of university research activity on students has been summarised by Jenkins (2004); several common themes arise:

- **Up-to-date courses - staff are real people**: There is evidence students perceive that their courses are up to date and that academic staff are interested in the subject they are studying. Through a member of staff's research interests keeping the course up to date, students could see that staff are 'real people'.

- **Many students are positive - but many don't see themselves as stakeholders**: Studies have demonstrated a mostly positive view about staff research. If staff research was used to keep their courses up to date, then students saw them as being current and stimulating. However, many students saw research as being somehow 'separate' from them - they didn't feel they were stakeholders in that part of their university's activity. Students were aware of the benefits of being in a research community, but felt excluded in many ways - most were aware of the negative impacts of staff research, particularly in terms of time management (staff absences and availability due to research).

- **Are some students indifferent?**: There is evidence that the level of students' involvement in their courses was related to their attitudes towards research. Students who came to university for 'social contacts' or for 'useful' (vocational) qualifications were indifferent, while those who came to further their own learning were positive. The only students who expressed a negative view of staff research were those who seemed to avoid contact with staff!

- **Student intellectual development**: There has been limited research on the effect of staff research on students' intellectual development - however, there have been studies on the impact of the US summer school research programmes (as described in some of the international exemplars), which have shown that students on such programmes become more confident as learners and more capable of thinking independently. The US National Science Foundation surveyed more than 14,000 students and mentors given undergraduate research opportunities (in NSF programmes) and found a major impact on participant's confidence, their understanding of research-related issues and an increase in their interest in careers in science and engineering.

Jenkins concluded that there was clear evidence of students valuing learning in a research-based environment, but with varying attitudes to staff research (possibly linked to the disciplines). However '…there is evidence that…institutions and departments may not be effectively supporting students to obtain maximum value from these opportunities or managing the negative impact…'.

Although there is limited evidence specifically for students from the engineering and built environment disciplines, most academic staff would recognise, or have directly experienced, most of the common themes described by Jenkins. From the discussions given here in section 3.2.3 and 3.3.4 on issues in engineering and built environment it may be inferred that students' perceptions of the role of research may be obscured by the inter-relationships between research, design and consultancy in the same way as academic staff. For example, in a study by During and Jenkins (2005) with focus groups of staff in the built environment, staff perceived that students did not always recognise that research is an important skill - one member of staff made the comment that '…*we* are not perhaps presenting it as something that is of value to them …'. Or perhaps students could not themselves distinguish between research and project learning or design. However, from the Durning and Jenkins study, staff did believe that understanding how knowledge is created in their discipline, and the development of research skills, was important not only in enhancing the students' capabilities as learners, but also in improving their employability - something that is obviously foremost in the minds of students embarking on degree programmes in engineering and the built environment in particular. This possible confusion in the minds of students was highlighted in a series of brief focus groups undertaken as part of the Hadfield and Carter survey of case studies (mentioned above). Students in engineering disciplines at one institution were asked to select some of their classes and initially place them in the Healey model - most students placed their classes equally in research-oriented, led and based, as may be expected in engineering. The students were also asked to reflect further on these classes in their own words - providing a valuable insight in their perception of the role of research in their learning. Students expressed a concern that too much of what they were learning was theoretical and removed from practical, real-world activities and some did not consider academic research as related to the 'real world'. The theoretical aspects of their classes was also emphasised in a plea for more hands-on experience and possible industrial relevance. This supports evidence that students have not been shown the connections between the various classes and activities in their course, and the relation to research and technology transfer. Possibly the link between course work and real world applications needs to be made more explicitly. Students may not realise that many applications in industry today were informed by academic research, and that future developments in industry are currently being explored by academics. Content could be made more 'real world' for students by emphasising connections between academia and industry that may not be obvious to them. This further highlights the wider dimensions to the research-teaching nexus described in section 3.3.4 in relation to the built environment (Senaratne, 2005) and the need to create teaching-industry (that is, real-world) links.

5.2 Linking teaching and research in departments

The Hadfield and Carter survey did not include departmental or institutional perspectives. Nevertheless, the results of studies in the UK on the departmental role in developing student attributes by linking research to teaching are consistent. In a study of students across disciplines at the University of Oxford, Trigwell (2006) concluded that:

> Given the considerable research that shows that deeper approaches to learning and lower surface approaches to learning are related to higher quality outcomes of student learning, students' perceptions that they are a part of a research-stimulated teaching environment would appear to be desirable…

As a consequence he recommended that:

> The relations between perceived research-stimulated teaching environments and approaches to learning suggest that action could be taken…to help more students to experience the benefits of research-stimulated teaching environments.

Creation of a research-stimulated teaching environment arguably cannot be done at the level of an individual academic delivering a particular class: it requires a more strategic outlook (indeed culture) at departmental level. However, in a study by JM Consulting (2000) for the Higher Education Funding Council for England:

> We found little evidence to suggest that synergies between teaching and research were managed or promoted at departmental or institutional level…. There were some attempts to manage teaching and research workloads in departments, partly to allow more time for research. Some strategies may be having the unintended consequence of driving research and teaching apart for some staff.

This finding, although almost a decade old, would probably still be familiar to the majority of academics in the UK, particularly with the continuing (but unavoidable) prominence of the RAE/REF in the institutional mindset. Further, in a study of academic staff in departments in the built environment, Durning and Jenkins (2005) found that their work:

> …demonstrates how issues of department organisation and culture - in particular the effective policy separation between teaching and research - result in failures to support staff to achieve potential synergies between these activities. Evidence is also provided that, in built environment disciplines there are distinctive features of teaching/research relations that need to be considered in department policies...

In addition:

> There were many of these staff who questioned the value of RAE-style research to their own and department practice, and to student learning.

In their report on the relationship between research and teaching in the science and engineering disciplines, Fasli et al (2009) concluded that (see also section 3.1.3):

> …there are very few dynamic links made between institutional and departmental strategic planning documents for research and teaching…the lack of a strategy meant that it was difficult to establish appropriate boundaries or to recognise constraints related to the discipline or curriculum within which staff could operate...

The disciplinary aspect of research-teaching linkages then comes to the fore again. In the built environment disciplines in particular there was as much emphasis on design and consultancy in practice-led subjects as on RAE-style research. Indeed, as pointed out by Roberts (2007) for architecture and Wood and Ellis (2007), academic staff in these disciplines did not communicate the research related to their RAE submissions to the students - the RAE-style research was considered a different type of activity from their requirement to train and educate accredited professionals. While in the engineering disciplines there is much less of a rift between academic staff's RAE research and the educational needs of the students (since many can participate and contribute to staff research in individual and group projects) there remains the tension between design, project learning and research.

Thus, various studies and research-evidence (Jenkins, Healey and Zetter (2007) provide a more complete review) suggest that the role of departmental culture and a more proactive and strategic approach to putting research-teaching linkages in place is essential if the necessary graduate attributes are to be acquired by the students. Fortunately, as part of their study, Jenkins, Healey and Zetter (2007) provided useful generic policy and practice suggestions for departments:

- **Strategy 1: Develop departmental and policy understanding**: Raise awareness of the need for making the research-teaching link to promote both generic and discipline specific understanding. This must be discussed openly by all academic and support staff, perhaps through departmental seminars or away-days.

- **Strategy 2: Review current practice and culture**: As part of the discussion, departments need to be (self-) aware of their own current practice and culture - possibly starting with a review of what is in place and why, including student perceptions, and possibly how departmental research projects or expertise is integrated into the student experience (if at all). Again, disciplinary issues need to be equally considered (such as the links with accreditation, design, consultancy and technology transfer in our case).

- **Strategy 3: Develop a set of related curricula interventions**: The curriculum is the key area in which interventions can be made - it is here that staff expertise in research (in its widest sense) can most effectively support student skills development. Focusing on the curriculum (what is delivered to the students) moves the focus away from the research activity of individual academics to how a department organises its resources, particularly staff, to support the student's experience of research. Naturally, the preceding review and proposed interventions have to be done in the context of relevant professional accreditation - however, this is a positive step, since in our disciplines we already have a framework for course review as part of the accreditation submission.

- **Strategy 4: Develop staffing policies**: Suggested specific strategies could include (more are given by Jenkins et al): deciding on a hiring policy - this may vary considerably from research-led departments to more teaching-focused ones; decide if individual staff should take on more specialist roles to support research-teaching links in a visible way; maximise the use of staff teams and consider the different approaches teams would use to curriculum development if they were part of research teams rather than subject teams; recognise and support staff, as they progress through their careers, who may wish to change their (research and teaching) roles in support of departmental objectives.

- **Strategy 5: Integrate policies and structures for teaching and research**: Review and revise teaching and research strategies in the light of each other - is there any commonality?; consider the role in teaching of research centres; review how laboratories, equipment, space allocation and technical support promote the perceived teaching-research link; review reward structure.

- **Strategy 6: Progress the link**: Continue to review and revise the research-teaching link in the department. Jenkins et al have provided a set of questions which departments can use over time to ensure the link continues to progress, rather than being a static, one-off, intervention.

Of course, it must be recognised that very few departments now have complete control of resources - in particular hiring policies, equipment budgets and space allocation. Much of this is shaped at institutional (or faculty/school) level and from external policies. Often this may not be helpful in progressing the link - for example, many universities still require separate research and teaching strategies, which are managed by different institutional committees, and hiring can be especially focused on RAE suitability. This means that there should also be an institutional policy on the research-teaching link (which could of course be implemented in different ways).

5.3 Recommendations

Finally, it is important that our recommendations are concise. The most important goal of this Enhancement Theme has been to recommend, generically and in each discipline group, a simple guide to how to start implementing the research-teaching linkages to improve the student experience (for all students) and ensure the requisite attributes are acquired.

Before attempting to implement any of these recommendations, those involved should start with Jenkins and Healey's (2005) report on institutional strategies for bringing teaching and research together, then turn to Jenkins, Healey and Zetter's (2007) report on linking teaching and research in disciplines and departments. These reports will serve to introduce any course team with responsibility for curriculum development (and accreditation) to the relevant research findings and the issues involved at both institutional and departmental level and the disciplinary perspectives. The next step would be to consider the relevant generic key recommendations from the overview report from this Enhancement Theme (Jenkins 2009):

- Departmental and school policies should be developed to promote systematic linking of research and teaching throughout degree programmes.

- Course teams, departments and schools should consider how to best develop explicitly a structured approach to developing research-type attributes across the curriculum.

- Attention should be given to ensuring that the final-year's focus on research-based attributes is effectively underpinned by structured interventions from year one.

- Particular attention needs to be given to year-one courses that support student introduction to disciplinary and professional communities of practice and develop students' 'research mindedness'. Upon graduation (and before), students need to be able to apply this 'research mindedness' to employment and their wider roles in society.

- There is the potential, and indeed the need, to progress this agenda through the use of assessment regimes that help students in developing and articulating these research-based graduate attributes. These assessments need to be recorded in ways that support graduate employability and make more transparent to employers the research knowledge and skills students have developed in higher education.

Of course, the implementation of these recommendations at departmental level has to be done in the context of faculty/school and institutional policies, but there remains a high degree of departmental autonomy, particularly at the level of curriculum development.

In the context of these three reports, the course team should reflect upon the discussions and case studies, and so on, given herein on engineering and the built environment for particular disciplinary issues. In particular three specific outcomes of this study can be identified:

- much staff research in our disciplines is applied research and consultancy or technology transfer with the related issue of training for practice. This 'knowledge economy' emphasis is also strongly apparent in how students experience research in curricula in programmes in our disciplines. In some of the built environment disciplines, this practical focus is arguably more evident, but there the pedagogic focus may bring students close to the research-based professional practice of academic staff.

- students' focus on entering professional practice-based careers brings a strong employment focus to the culture of these courses. While readily appreciating the importance of consultancy-style research and technology transfer with industry, special curricula emphasis may be needed to bring out the importance to them of more traditional research.

- professional bodies significantly shape the curricula in these programmes. They tend to put more emphasis on the skills and aptitudes for using the findings of research than on the expertise to conduct research. However, research and research-type activities are becoming more evident in the accreditation criteria for courses at undergraduate levels.

In making more specific recommendations to course teams tasked with implementing research-teaching links, exploiting our broad view from the preparation of this report, we would stress the importance of the following:

- **Adopt the Jenkins, Healey and Zetter (2007) strategy for implementation at a departmental level**, described here in section 5.2. Avoid implementation by specific academics in what seem appropriate classes and move towards a more coherent and integrated curriculum design both vertically and horizontally.

- **Read carefully the case studies and international exemplars in this report**. They provide a range of examples of good practice, which can be enhanced by a more integrated, departmental approach.

- **Don't keep the implementation of the links separate from related requirements** for student skills development, in particular accreditation. In this way, significant changes need not be prohibitively expensive. The creation of research-teaching linkages and accreditation both address graduate attributes - adopt a holistic approach. For example, use the need to prepare submissions for accreditation to relevant professional bodies in a positive way and as a lever for implementing research-teaching linkages. In our disciplines we already have this framework to follow. Identify and make explicit the professional competencies with the graduate attributes of students experiencing a research culture. But also recognise the current limitations of these competencies in relation to research.

- **Identify the distinctions between the various components of professional training** such as RAE discovery research, industry links: technology transfer and consultancy type research, design, problem solving and project learning discussed in section 3 here, and the different skills and attributes that may be associated with these (often overlapping) activities. Ensure that both the distinctions and common features of each are clear to the students (perhaps as part of their professional development planning).

- **Recognise the benefits of developing an effective graduate through research-teaching linkages**. The benefit will not only be to the student experience, but also to the academic staff, who, too often have had to separate their teaching and research or technology transfer activities. This is particularly true for the engineering and built environment disciplines - the sense of a professional community, where our role is to prepare the student for professional practice, can only be enhanced and teaching thereby improved.

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