UK Approaches to Engineering Project-Based Learning

White Paper sponsored by the Bernard M. Gordon-MIT Engineering Leadership Program

Dr. Ruth Graham

Email: ruth@rhgraham.org

Executive summary

This report presents the findings of a snapshot review of UK approaches to *engineering project-based learning (PjBL)* conducted between July and December 2009. The review aims to provide insight into the context for PjBL in UK engineering education as well as identify a number of highly-regarded best practice approaches. It does not therefore provide an exhaustive survey of the field.

Much of the information gathered during the review was collected through detailed interviews with international experts in engineering education, PjBL and problem-based learning (PBL). Over 70 individuals were consulted during the research phase of the study.

The report discusses the opportunities and challenges for implementing PjBL in the UK engineering curriculum, identifies a number of UK universities whose approaches are particularly highly-regarded and presents some of the key themes evident in UK engineering PjBL practice. The report also presents 7 UK case studies of engineering PjBL that were commended by their UK and international peers as offering particularly robust, successful and transferable models. Of these case studies, the example taken from Queen Mary, University of London offers perhaps the most engaging and easily transferable model.

For the future development of engineering PjBL within the UK, three key issues emerge.

Firstly, there is currently a lack of confidence and/or knowledge amongst many UK engineering faculty in the design and application of both assessment and evaluation processes for PjBL experiences. For this reason, perhaps, many current PjBL activities impose a heavy burden of assessment on students and staff while, at the same time, incorporating very limited evaluations of the learning processes and outcomes.

Secondly, the review highlights a number of issues surrounding the sustainability of many UK engineering PjBL experiences. The majority of PjBL activities are taken forward by a single ‘champion’, often operating in relative isolation. As the resulting experiences are rarely continued beyond the tenure of this ‘champion’, the long-term sustainability of many PjBL activities is often difficult to assess. However, within the UK, a number of institutions - most notably Coventry University and UCL - are currently developing a more structured approach to implementing PjBL within the engineering curriculum. Such developments will not only provide more sustainable support systems for new PjBL activities but are also likely to have a wider impact on the adoption of PjBL in engineering across the UK.

A third factor is likely to make the issue of sustainability more pressing. Despite growing interest in the application of PjBL in the UK, the evidence from the review raises some concerns about funding and mechanisms for supporting such activities in the future. The UK government’s cutbacks to higher education funding and the imminent closure of a number of the *Centres for Excellence in Teaching and Learning* may well limit the local and national sources of support for future engineering PjBL activity.

Acknowledgements

This report was undertaken with financial support from the Gordon-MIT Engineering Leadership Program at MIT.

I am particularly grateful to the engineering faculty, education professionals and engineering students from the UK and across the world who contributed so generously to the review by giving their time and sharing their knowledge and expertise.

Contents

1 Introduction

1.1 Context

The Bernard M. Gordon-MIT Engineering Leadership Program (ELP) was established in 2007 with the goal to '*help MIT's undergraduate engineering students develop the skills, tools, and character they will need as future leaders in the world of engineering practice'*. Project-based learning (PjBL) lies at the heart of the program, as the key mechanism for students to develop and reflect on their individual engineering leadership skills. The program therefore has a keen interest in developing tools to improve the efficacy of engineering project-based experiences and learning from best international practice in the field.

It has been observed that many of the well-publicized examples of engineering PjBL across the world do not offer transferable approaches that could be readily adopted elsewhere – such experiences often operate with high financial input, small class-sizes and depend on access to intensive support and specialist expertise/equipment. The Gordon-MIT ELP is looking, in particular, at the development of transferable models of PjBL which offer a flexible approach that can be used across different countries, institutions and educational structures.

A series of research studies was therefore commissioned, looking at best practice *transferable* approaches to engineering PjBL across the world. The first of these studies, as documented here, is focused on the United Kingdom (UK). It is hoped that this study can be used a resource both by those interested in the PjBL approach as well as those considering the establishment of new activities within engineering schools across the world.

For the purposes of this study, the broad definition of project-based learning given by Prince and Felder[1] has been adopted:

> *'Project-based learning begins with an assignment to carry out one or more tasks that lead to the production of a final product—a design, a model, a device or a computer simulation. The culmination of the project is normally a written and/or oral report summarizing the procedure used to produce the product and presenting the outcome.'*

In practice, many engineering education activities developed on the basis of inductive instructional methods – active learning, inquiry-led learning, problem-based learning etc. – focus on a fixed deliverable and therefore fall within this definition of PjBL.

---

[1] Prince, M. J. and Felder, R. M., 2006. Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education, 95*(2), 123-138.

1.2 Focus/process

This report presents the findings of a 'snap-shot' review of best practice in engineering PjBL in the UK, conducted between July and December 2009. It presents a selection of highly regarded case study examples of engineering PjBL that could, potentially, be adopted 'out-of-the-box' at other institutions. Only case studies that were seen by the contributors to the study as offering a robust, successful and transferable approach have been included in this report. All examples included operate on low budgets, accommodate relatively high-class sizes, and do not require significant levels of expertise/support/equipment for their successful operation. Further guidance on how the 'transferability' of a PjBL model has been defined in the review is given in Section 5 of this report.

The report is not an exhaustive examination of the field, but seeks to provide an insight into best practice in UK engineering PjBL and highlight particular challenges and opportunities in this area.

The process adopted to identify and investigate 'best practice' during the review is outlined below.

1. *Targeted interviews:* interviews with experts in the field to better understand UK and global trends in engineering PjBL, highlight UK case studies of best practice and identify further contacts for follow-up interviews. The interviewees targeted were:
    - *international experts in engineering PjBL and problem-based learning (PBL);*
    - *UK and international experts and/or innovators in engineering education;*
    - *experts in PjBL and PBL in UK higher-education;*
    - *Heads of Department or Directors of Studies in leading UK engineering schools.*

    Interviews were designed to gather information and capture expert judgment to better understand the overall context for the adoption of engineering PjBL in the UK, identify current/future centres of excellence and highlight those most highly-regarded examples of PjBL in the curriculum.
2. *Investigation of targeted programs*: further investigation of the most highly regarded examples of engineering PjBL, as highlighted during the interview phase, to identify those that are both successful and transferable.

During the research phase of this study, over 70 experts and practitioners in engineering education, PjBL and PBL have been consulted, as listed in Appendix A.

Engineering PjBL within the UK has been the key focus of this work. However, it was also observed that many approaches developed in Australia also offer highly transferable models - as with the UK, much of the Australian engineering education system caters to large class sizes with relatively small budgets and has seen significant advances in PjBL over the past decade. For this reason, a number of particularly interesting case study examples from Australia have also been included in Appendix B.

All web-site references given in this report were last accessed on 14th January 2010.

2 Engineering PjBL in the UK

In line with many other countries across the world, over the past 10 years the UK has taken a more active interest in the approach, ethos and quality of its engineering higher education. A number of high-profile reports published in recent years[2,3,4] have started to engage both engineering faculty and departmental senior management in a dialogue about change in engineering education.

PjBL is currently attracting particular interest within the UK engineering education community. For example, in June 2009 the *Engineering Subject Centre* hosted a 2-day conference[5] in engineering PjBL. A 2-day UK workshop[6] was also organized by a US delegation, seeking to identify potential areas for international research collaboration in engineering PjBL. Other recent initiatives focused on the adoption of PjBL and PBL in engineering and related disciplines in the UK include *PBLE*[7], *Project LeAp*[8] and a Higher Education Funding Council for England (HEFCE) supported a joint project[9] between UCL, Bristol University and UMIST.

Outlined in this section is a summary of the feedback on the state of engineering PjBL in the UK, captured during the interview phase of this study.

2.1 Overall observations

It was observed by a number interviewees that, across the world, the UK currently offers one of the most diverse approaches to PjBL, both in the numbers of disciplines that have embraced this model and the ways in which PjBL has been used in the classroom. The UK is seen to be more 'maverick' in its approaches to PjBL/PBL and less tied than other countries to the classic models such as that developed at McMaster University. This more unconventional approach may be due to the fact that most UK engineering PjBL experiences are developed by engineering faculty with no formal training in education and therefore perhaps with fewer preconceptions about what an effective PjBL activity 'should look like'.

---

[2] HM Treasury, 2005, *Cox Review of Creativity in Business: Building on the UK's Strengths*, HMSO (www.hm-treasury.gov.uk/coxreview_index.htm)

[3] The Royal Academy of Engineering, 2007, *Educating Engineers for the 21st Century* (www.raeng.org.uk/news/releases/pdf/Educating_Engineers.pdf)

[4] HM Treasury, 2007, *The Race to the Top: A Review of Government's Science and Innovation Policies*, HMSO (www.hm-treasury.gov.uk/sainsbury_index.htm)

[5] Event: *Enhancing Project Based Learning in Engineering*, 23rd-24th June 2009, Loughborough University

[6] Event: *International Symposium for Research on PBL in Engineering Education*, 24th-25th June 2009, Loughborough University

[7] Web-resource: *Project Based Learning in Engineering* (www.pble.ac.uk)

[8] Web resource: PossiBiLities: A Practice Guide to Problem-based Learning in Physics and Astronomy, The Higher Education Academy Physical Sciences Centre, March 2005 (www.le.ac.uk/leap/pblguide.pdf)

[9] Canavan, B., 2008. A summary of the findings from an evaluation of problem-based learning carried out at three UK universities, *International Journal of Electrical Engineering Education*, 45(2) 175-180.

The majority of engineering PjBL in the UK is delivered within discrete modules by a small number of faculty 'champions', often with minimal support from departmental/school senior management or external bodies. One significant problem with this approach is that the modules/experiences are rarely sustained beyond the tenure of the champions/s. This issue emerged very strongly in the study – a great many of the PjBL programs recommended by experts during the interview phase were subsequently found to be no longer operational, due to the module leader either having retired or moved on. This dependence on a single individual is particularly significant when one considers the time required to hone and fully embed a PjBL activity into the curriculum. One faculty interviewed observed that 5-10 years was probably a minimum time requirement to achieve this.

In recent years, two key informal communities have helped to connect a number of UK engineering faculty working in PjBL – one a loose network, connected via the Engineering Subject Centre[10] and the other the UK-branch of the international CDIO[11] initiative. Many interviewees commented on the important role of these networks in providing new ideas and practical support in the development and implementation of new PjBL experiences. Of those UK institutions that have placed a particular emphasis on engineering PjBL (a selection of which are highlighted in Section 3), around half are connected into one or both of these networks. The networks provide useful dissemination routes and clearly have improved the UK-wide visibility of the participating institutions - the majority of UK engineering faculty interviewed for this study were only aware of PjBL activities undertaken within institutions actively involved in one of these two communities. In contrast, however, the UK institutions identified by non-UK interviewees as holding a strong *international* reputation in engineering PjBL tended to be less engaged with these networks. It is also interesting to note that very little interaction is apparent between the UK higher education or PBL research communities, and the UK engineering education community engaged in PBL or PjBL. Where collaborations do occur, they are often confined within a single institution.

In recent years, another more formal mechanism for improving university education in England has also helped to support the application of PjBL in the engineering curriculum- the *Centres for Excellence in Teaching and Learning*[12] (CETLs). 74 CETL centres were established in 2005 through the national higher education funding agency for England (HEFCE) at a total cost of £315m. With the central 5-year funding of the centres due for completion this year, however, it is not yet clear the extent to which the various CETLs will continue to operate beyond 2010. A number of interviewees expressed concern that many of

---

[10] Web-site: Engineering Subject Centre (www.engsc.ac.uk/)

[11] Web-site: CDIO Initiative (www.cdio.org/)

[12] *Centres of Excellence for Teaching and Learning*, Higher Education Funding Council for England (www.hefce.ac.uk/Learning/TInits/cetl)

the engineering project-based activities developed through the CETLs may not be sustained once this support is withdrawn.

2.2 PjBL in practice

There is a broad range of different approaches taken by UK engineering schools in designing, delivering and disseminating their PjBL activities. A number of institutions have adopted PjBL widely across their programs (as discussed in more detail in Section 3) while others have implemented only the minimum PjBL experiences required by the UK accreditation standards, UK SPEC[13]. At a minimum, the basic UK approach to engineering PjBL typically comprises a first-year group-based 'challenge', often undertaken during the induction weeks, and both a group and individual major project during the final year of study. In contrast to the classic image of an 'undergraduate engineering project', less than half of the highly regarded UK examples of PjBL identified in this study involved any practical or 'hands-on' element.

Amongst UK engineering faculty, there is clearly a wide variety of definitions of PjBL, and some confusion about the differences between PBL and PjBL. For this reason, perhaps, many engineering departments are choosing to define their activities more broadly, using terms such as 'activity-led learning'.

A number of UK engineering faculty identified *module evaluation* as an area of concern. Within the UK, very few PjBL activities currently have associated program evaluations, beyond the mandatory student satisfaction surveys. A greater integration of program evaluations may help to provide real evidence for the impact of PjBL on student learning and outcomes, as compared to more traditional lecture-based approaches, which may (if positive impacts are indicated) assist with the wider adoption of this approach.

Many faculty also reported a lack of knowledge and/or confidence in the design and implementation of *assessment* process for their PjBL experiences. Perhaps for this reason, many UK examples of engineering PjBL incorporate significant levels of summative assessment, implemented throughout the experience. In addition, many approaches are often highly structured, with the overall task broken down into stages that groups must complete and deliver on schedule. Such approaches have often been developed to support 'weaker' students and encourage a transition into independent learning. These more prescriptive forms of PjBL, however, were seen by a number of interviewees as "*missing the key energizing element*" of such experiences, through not allowing the students the space to create and explore new ideas.

Of those most highly regarded examples of engineering PjBL in the UK (a selection of which are presented in Section 5), the most apparent commonalities relate to the module leaders in each case. The leaders of the most highly-regarded modules tend to be personally committed to excellence in education, benefit from

[13] UK Standard for Professional Engineering Competence, Engineering Council *(www.engc.org.uk/professional-qualifications/standards/uk-spec.aspx)*

a high level of autonomy in the design and operation of their modules and often draw from significant levels of experience in engineering industry.

A number of key themes emerged as areas of interest amongst UK engineering faculty in the development of new PjBL experiences in the coming years:

- a greater emphasis on embedding *sustainability* and *ethics* within the project context;
- the creation of new cross-campus multi-disciplinary projects, centered on engineering challenges;
- changing traditional laboratory experiments into more open-ended PjBL/PBL scenarios.

2.3 Drivers and barriers

Across the world, engineering faculty report a number of common motivations for the integration of PjBL into the curriculum, such as contextualizing the engineering fundamentals, responding to changes in accreditation requirements or broadening the students' skill base.

The study highlighted a number of specific drivers that were most strongly associated with current and potential future implementations of PjBL in the UK. As a broad contextual driver, many UK interviewees referred to the strong calls for change from government, industry and professional bodies to ensure that engineering graduates were equipped with a broader set of professional skills and attitudes and a greater experience of solving 'real' engineering problems.

A second and more significant driver for the adoption PjBL appears to be student recruitment and retention. For this reason, many programs concentrate their PjBL experiences on the first year of study. With recruitment as a major motivator, a number of UK engineering schools have rebranded their education around project-based or active learning. Recent government changes to university funding that increase the penalties on institutions where undergraduate degree programs enroll beyond their allocated number of students is likely to further intensify the focus on student retention. In other words, departments will seek to maximize their income for a capped number of places by minimizing dropout throughout the 3-4 year courses. One concern raised by a number of those interviewed, however, with recruitment/retention being such a strong driver for educational change, is that the resulting curriculum can simply focus on '*wow factor'* projects rather than the educational outcomes and long-term benefits to the students.

It is also interesting to note that a small number of interviewees identified *Bologna compliance* as a possible driver for future interest in engineering PjBL. It is not yet clear whether the UK will be required to change the structure and duration of its undergraduate programs in accordance with the *Bologna* agreement. If compliance is required, a number of engineering schools are considering integrating engineering-related vacation activities into the curriculum, in order to increase the number of credit-bearing modules in each year. If such plans are taken forward, new mechanisms will need to be developed in order to support these mainly project-based activities within the curriculum.

Although there is clearly a significant level of interest in engineering PjBL in the UK, this approach is by no means widespread. In fact, a number of the interviewees for the study commented that, unless action could be taken, the application of PjBL in the UK engineering curriculum may actually decline in the future. Outlined below are the key factors that are seen to *impede* the current and future implementation of engineering PjBL within the UK.

- ***Faculty time***: One central issue within UK higher education is the national research assessment process, previously called the *Research Assessment Exercise* (RAE) and now, in a revised format, the *Research Excellence Framework* (REF). Instituted by the UK's higher education funding councils, this is a periodic peer-led review of the quality of research in all disciplines in UK universities. Many view the intensive pressure for faculty to maximise their research performance (particularly research grant income and publications in high-impact journals) to secure high rankings in the RAE/REF as disincentivising excellence in education. Many interviewees identified PjBL as an activity that demands significant amounts of time to both design and support, and reported difficulty in securing this from their own schedule and that of their colleagues.

- ***Faculty experience***: A number of interviewees commented on the numbers of UK engineering faculty with industry experience, which been in decline over the past 10-20 years. Many view such experience as an important element in designing and supporting meaningful 'real-world' project-based activities for the students. One interviewee commented that the "*lack of such experience means that staff are reluctant to move outside their relatively narrow research 'comfort zone' where they are confident of their mastery of the relevant facts into an area where they will inevitably be exposed to areas new to them*".

- ***Facilitator training***. The training of facilitators appears to be a significant issue. For many PjBL activities, a large number of facilitators are often required to oversee and support the group working process. In many cases, PhD students or post-docs are employed in this task, but many struggle with the concept of facilitating the group activity while providing only minimal technical guidance.

- ***Efficacy of PjBL*** A number of faculty reported a reluctance to adopt PjBL on a wider basis within their departments until 'proof' of its efficacy could be provided when compared to more traditional educational approaches. A number of those interviewed commented that apparent positive impacts of new PjBL experiences may simply result from students receiving higher levels of faculty time rather than any intrinsic benefits from the educational approach.

- ***Resources***: Insufficient departmental resources appear to be a significant barrier to the wider adoption of PjBL in the UK curriculum, both in terms of staffing time and materials/equipment/space costs for the projects themselves. The issue of resourcing is likely to become more pressing in the future, particularly following the recent government announcement of significant cuts to the funding for UK higher education. In addition, with government funding to the CETL centres ceasing in 2010, external resources for such departmental endeavors may also be limited.

- ***Accreditation concerns***: A number of engineering faculty reported concerns about whether the inclusion of significant PjBL experiences within the curriculum were compliant with the program accreditation requirements. The study, however, identified no UK engineering program for which accreditation has not been granted on the basis of their PjBL offering.

- ***Learning spaces***: A number of UK engineering faculty interviewed identified a lack of appropriate learning spaces as the key barrier to a wider implementation of PjBL within their curriculum. For many, the compromise of dividing the student cohort between a number of inadequately equipped smaller spaces would have too great an impact on the learning experience for the use of PjBL to be a viable long-term option. However, following many years of underinvestment in university infrastructures at a national level, a surprising number of engineering schools (such as University of Liverpool, Coventry University, Birmingham University and Imperial College London) have recently completed or are planning new or totally refurbished buildings, incorporating new learning spaces. In many of these cases, the new builds appear either to have been influenced by or to be triggering new shifts towards active learning. Such developments present a significant opportunity for considering new modes of teaching and learning at these institutions.

3 UK engineering PjBL at an institutional level

The study highlighted a number of UK institutions that have focused particular attention on engineering PjBL. This section identifies a selection of UK institutions whose activities in engineering PjBL are both highly-regarded and successful. Two institutions are highlighted in particular - Coventry University and University College London (UCL) – who have taken a more unusual and strategic approach to the reform of their undergraduate engineering education around PjBL/PBL.

3.1 *Faculty of Engineering and Computing,* Coventry University

The educational reform seen in the *Faculty of Engineering and Computing* at Coventry University is currently at an early stage, but potentially represents one of the most interesting developments in PjBL across the UK. The activities at Coventry[14,15] combine a number of elements that are of particular interest:

1. a new 'activity-led' curriculum, currently under implementation, which incorporates full-time 6-week projects at the start of each academic year in each department. Early results from an evaluation within the Faculty suggest that the initial pilot 6-week experience (held in academic year 2008/09) may have produced a significant positive impact on the participating students' final year examination results.

2. a new £60m building - due for completion in 2011 – whose design is informed by some of the most innovative examples of engineering active learning spaces from across the world;

3. establishment of a new *Student Experience Enhancement Unit* within the Faculty that trains and employs undergraduate engineers to support and advise their peers as well as engage in engineering education research and enhancement activities;

One factor that makes the efforts at Coventry University particularly unusual within a UK context is the levels of support their endeavors have received from the institution's senior management, including the Dean of the School and the Vice Chancellor of the university. One result of this high-level backing and engagement is a vision and reform program that appears to be genuinely school-wide. Although Coventry is clearly looking at the international rather national stage in their vision, if successful, they are well placed to become a UK-leader in engineering PjBL.

---

[14] Web-site: '*Activity-led' learning at in the Faculty of Engineering and Computing at Coventry University* (wwwm.coventry.ac.uk/engineeringandcomputing/aradicalfuture/Pages/activityledlearning.aspx)

[15] Wilson-Medhurst, S., Dunn, I., White, P., Farmer, R. and Lawson, D., 2008. Developing Activity Led Learning in the Faculty of Engineering and Computing at Coventry University through a continuous improvement change process. Proceedings of the *Research Symposium on Problem Based Learning in Engineering and Science Education*. Aalborg, Denmark, 3 June–1 July 2008.

3.2 *Faculty of Engineering Sciences,* UCL

Two rather different and relatively independent developments in PjBL/PBL have been implemented in the Faculty of Engineering Sciences at UCL, as discussed in turn below.

The *Department of Electronic and Electrical Engineering* has adopted a 'purest' application of PBL within a number of their modules[16], which are led by a small group of faculty 'champions'. These developments were the most highly-regarded UK application of engineering PBL/PjBL emerging from the interview phase of the study, particularly amongst those from an educational background. The approach was first adopted in 2001 as part of a broader project to implement PBL in three electrical engineering departments across the UK. Within the *Electronic and Electrical Engineering Department* at UCL, PBL activities have now been implemented in a number of modules across the first three years of the curriculum. A case study of one such module is given in Section 5.6.

The *Department of Civil, Environmental and Geomatic Engineering* at UCL has taken a more comprehensive approach to educational reform and recently restructured both their undergraduate *recruitment* procedures and *curriculum*:

- *Recruitment*: the department's mission is focused on educating the UK's *'future leaders'* in all spheres, not just in civil engineering. The department have therefore broadened their entry requirements to accept students with qualifications in any subject area, provided they achieved '*straight A-grades'* in their A-levels or equivalent. They are also looking to market their programs more widely, to attract prospective engineering students from non-traditional backgrounds.
- *Curriculum*: the curriculum has been re-designed and structured around 4 'clusters' - *context*, *mechanisms*, *tools* and *change* – rather than the traditional engineering science disciplines. The first two years of the program now operate on 5 week cycles, where students are given a PjBL 'scenario' at the beginning of the cycle, are provided with 4 weeks of relevant lecture material, and then spend an intensive one week working in teams on the problem set.

The first cohort of students educated under the new curriculum will be graduating in 2010, and the changes already appear to have had a very positive impact, with drop-out rates reduced almost to zero and very favorable feedback from students and employers. The department is planning a further, and more radical, innovation to the curriculum in the coming years, through integrating one overarching project that will involve students in all 4 year groups. It is anticipated that these program-wide projects will be strongly linked to industry and students will be working in mixed year-group teams.

---

[16] Michell, J. E. and Smith, J., 2008. Case study of the introduction of problem-based earning in electronic engineering, *International Journal of Electrical Engineering Education*, 45(2) 131-143.

3.3 Additional institutions focusing on PjBL

Outlined below is a selection of UK institutions that have particularly focused on engineering PjBL in recent years, in additional to those described in Sections 3.1 and 3.2. It should be noted that this list is not exhaustive, and there are elements of very good practice in PjBL in many other UK institutions.

- ***Imperial College London***: a number of interesting extra-curricular activities are in operation at Imperial College London that are wholly led by undergraduates from the Faculty of Engineering. Greater levels of centralised support are now being offered to these projects through the Faculty's *EnVision*[17] project. Student initiatives include the El Salvador Project[18] and E.Quinox[19]

- ***Loughborough University***: Loughborough University hosts both the *Engineering Centre for Excellence in Teaching and Learning*[20] and the *Engineering Subject Centre*[21] and therefore represents a current centre of gravity for engineering education in the UK. Across the school, there are some examples of very good practice in PjBL, particularly in their industry-focused initiatives.

- ***Northumbria University***: Northumbria University has been interested in PjBL for a number of years. One pilot initiative is a masters in *Multidisciplinary Design Innovation*, where groups of design, technology and business students are tasked with simple open-ended challenges.

- ***Queen Mary, University of London***: around a quarter of the first and second year curriculum is based around PBL[22] in the *Department of Materials* at Queen Mary, University of London, incorporating a number of thoughtfully designed and engaging modules.

- ***Queen's University Belfast***: The *School of Mechanical and Aerospace Engineering* places a significant emphasis on PjBL, particularly in the first and final year of study. Much of this project-based approach has been adopted through the CDIO[11] framework. The university also hosts the *Centre for Excellence in Active and Interactive Learning*[23].

- ***Sheffield Hallam University***: Sheffield Hallam University hosts the *Centre for Promoting Learning Autonomy*[24] (with significant activity in engineering) as well as one of the few UK Professors of Engineering Education. The *Department for Engineering and Technology* are clearly

---

17 Web-site: EnVision, Faculty of Engineering, Imperial College London (www.imperial.ac.uk/envision)

18 Web-site: El Salvador Project, Imperial College London (www.elsalvadorproject.org.uk)

19 Web-site: E.Quinox, Imperial College London (www.e.quinox.org)

20 Web-site: *engCETL: Linking Education with Industry*, Loughborough University (www.engcetl.ac.uk/)

21 Web-site: *Higher Education Academy Subject Centres* (www.heacademy.ac.uk/ourwork/networks/subjectcentres)

22 Web-site: *Problem-Based Learning*, Department of Materials, Queen Mary University of London (www.materials.qmul.ac.uk/pbl/)

23 Web-site: *Centre for Excellence in Active and Interactive Learning, Queen's University Belfast* (www.qub.ac.uk/sites/CentreforExcellenceinActiveandInteractiveLearning)

24 Web-site: *Centre for Promoting Learner Autonomy*, Sheffield Hallam University (http://extra.shu.ac.uk/cetl/cpla/cplahome.html)

committed to innovation and excellence in engineering education and have developed a number of interesting new modules based around PjBL.

- ***University of Cambridge***: the *Engineering Department* supports a number of PjBL experiences, both within the curriculum as well as through student-led extra-curricular projects. The *Manufacturing Engineering* Tripos option, operating throughout the 3rd and 4th year of study, offers a range of project activities with strong links to industry.

- ***University of Hertfordshire***: the *School of Aerospace, Automotive and Design Engineering* at the University of Herefordshire has a strong reputation in curricular and co-curricular team-based 'design and build' experiences. Highly-regarded examples include various projects for undergraduates to design, build and test rockets[25].

- ***University of Liverpool***: the *School of Engineering* at the University of Liverpool has adopted an *active learning* approach[26] and incorporate significant group project work throughout their programs. Highly-regarded examples include the 'virtual projects' module[27], where students are tasked with 'culturally neutral' challenges on which to develop a business case.

- ***University* of Manchester**: in 2001, Victoria University of Manchester re-structured its engineering curriculum around PBL. Shortly after this change, Victoria University of Manchester and the University of Manchester Institute of Science and Technology (UMIST) universities merged to form the University of Manchester. It is acknowledged that, as the two curricula were combined, some of the momentum for the development and integration of PBL experiences was lost. There are still, however, many examples of good practice in PBL and PjBL in the combined programs, a number of which are designed around enquiry-based learning.

- ***University of Strathclyde***: a number of years ago, the *Department of Mechanical Engineering* at the University of Strathclyde re-designed the first 3 semesters of their program around PjBL with a view to engaging and motivating the students. One highly-regarded element of this new program is the first year *Mechanical Dissection* module[28].

---

[25] Web-site: Rocketry at the University of Hertfordshire (www.rockets.herts.ac.uk/)

[26] Web-site: *Active Learning for the Liverpool Engineer*, Department of Engineering, University of Liverpool (www.liv.ac.uk/engdept/active_learning/index.htm)

[27] Goodhew, P., 2009. Teaching teamwork and project management using virtual projects, *5th International CDIO Conference*, Singapore, 7-10 June 2009.

[28] Web resource: Barker, P. and McLaren, A.,2005).Teaching First Year Design by Mechanical Dissection. *Engineering Subject Centre*. (www.engsc.ac.uk/downloads/mechdissesction.pdf)

4 Key themes in UK PjBL practice

From the study, a number of broad themes emerged amongst some of the most highly-rated examples of engineering PjBL in the UK. Outlined below is a selection of these themes for a range of potentially transferable[*] approaches to PjBL.

- ***'Icebreaker' competitions***: full-time immersive group projects in the induction week/s for new first year students. Highly-regarded examples include the induction week activities at the *School of Engineering Science* at the University of Southampton[29] and the 'two week creations' in the *Department of Engineering* at the University of Liverpool[30].

- ***Partnerships with real on-going constructions***: final year civil engineering projects whereby student groups work on large-scale design projects that mirror real local developments, with strong input from the construction company involved. Examples include the capstone *Inter-disciplinary Group Project* at Liverpool University[31]. An international example, the *Civil Engineering Design Project* at the University of South Australia[32] is included as a case study in Appendix B.

- ***Entrepreneurship and product design***: capstone group projects for students to design an innovative product and develop an associated business plan for taking the product to market. In many examples of this approach, students are asked to deliver an 'elevator pitch' of their ideas to an external industry panel. Highly regarded examples of this approach include the *Marketing and Business Planning* module at Queen's University Belfast[33] and the *Technology Strategy and Business Planning* module at the University of Sheffield (which is included as a case study in Section 5.3).

- ***Video production and showcasing***: introductory modules, requiring student groups to design, produce and showcase a short video providing insight into a technical engineering subject area. For example, during this year's induction week, 1st and 2nd year students in *Civil Engineering* at Imperial College London produced and showcased short videos on London architecture. Another example from Sheffield Hallam University is included as a case study in Section 5.5.

---

[*] See Section 5 for the broad definition used here to characterise 'transferability'

[29] Web-resource: Engineering Subject Centre Teaching Awards 2006: *Design, build, test, float, fly and race – the School of Engineering Sciences induction week* (www.engsc.ac.uk/downloads/awards/takeda.pdf)

[30] Web-site: Icebreaker Introduction Week, University of Liverpool (www.liv.ac.uk/engdept/icebreaker_intro.htm)

[31] Undergraduate module: Inter-disciplinary Design Project, Civil Engineering, Department of Engineering, University of Liverpool

[32] Mills, J.E., 2007. Multiple assessment strategies for capstone civil engineering class design project. 18th Annual conference of Australasian Association for Engineering Education, Melbourne, Australia 10-12 December 2007.

[33] Web-resource: *An Integrated Approach to Entrepreneurship*, Queens University (www.engsc.ac.uk/downloads/Entre/belfast.pdf)

- ***Robot competitions***: projects, often in the 2nd year of study, for student groups to design and build robots to compete in a variety of different challenges. Examples include the *Stamp Olympiad* at Loughborough University [34] where robots compete in various 'sporting' events and the *Embedded Systems Project* at the University of Manchester [35] where Mechatronics students compete in a line-following robot race. A number of universities base these exercises around *Lego Mindstorm* robots, such as a creative problem-solving first-year module[36] at the University of Northampton.

- ***Artifact analysis***: projects which require student groups to each take one element of a more complex engineering product, such as a car, and investigate its properties, function, design and manufacture. One example of this approach is the *Mechanical Dissection* module in Mechanical Engineering at the University of Strathclyde[28].

- ***Crime scene investigations:*** a number of institutions have developed project-based crime-scene scenarios, where student groups are asked to identify the cause of an accident/crime. Examples include the 6-week full-time air accident investigation activity for first-year Aerospace students at Coventry University and the crime scene investigation in the *Materials with Forensics* project at Queen Mary, University of London (included as a case study in Section 5.2).

A number of additional themes in engineering PjBL in the UK offer a less transferable model and therefore have not been highlighted as case studies in this report. Many of these examples are both high-cost and cater to low cohort numbers, and often depend on access to specialist networks, equipment and learning spaces. Highly-regarded examples of these less transferable approaches are outlined below.

- ***Energy-efficient high-speed vehicles***: *Formula Student* (the UK equivalent of Formula SAE) is well established as a curricular and co-curricular activity in engineering schools across the UK. A number of schools, however, are now developing high-speed vehicles using alternative energies. Many such projects incorporate a strong link to the university's research activity in the area. Highly-regarded examples of such projects are *Imperial Racing Green* at Imperial College London[37], producing an electric-hybrid fuel-cell vehicle and *UH Racing* at the University of Hertfordshire[38], developing a hydrogen-powered vehicle.

---

[34] Flint, J., Godfrey, P. and Panagamuwa C., 2009. Using Robots in Project-Based Learning, Presentation at the *Enhancing Project Based Learning conference*, Loughborough University, June 2009. (www.engsc.ac.uk/nef/events/documents/pbl/Developing-project-management-skills-through-using-robots.pdf)

[35] Barnes, M., Bailey, M. Green, P. R. and Foster, D. A., 2006. Teaching Embedded Microprocessor Systems by Enquiry-Based Group Learning, *International Journal of Electrical Engineering Education*, 43(1), 1-14.

[36] Adams, J. P. and Turner, S., 2008. Problem Solving and Creativity for Undergraduate Engineers: process or product? *Engineering Education 2008*, Loughborough University, UK 16-18 July 2008.

[37] Web-site: *Imperial Racing Green*, Imperial College London (www.union.ic.ac.uk/rcc/racinggreen/)

[38] Web-site: *UH Racing*, University of Hertfordshire (www.racing.herts.ac.uk)

- ***Multi-disciplinary sustainability***: there is considerable interest in the development of new multi-disciplinary experiences for engineering undergraduates, and a number of the early activities developed in this area have a sustainability theme. One example is the *Eco-House* at Sheffield Hallam University[39], where students from across the engineering school come together to build a one fifth working scale model of an eco-house.

- ***'Low-tech' community-based projects***: through established partnerships with development agencies and charities, final year student groups are asked to develop robust and sustainable solutions to solve real community problems, typically in the third world. Groups may be asked to design and build a bread oven for use in Uganda or produce a wheelchair from bicycle parts. Examples include the *Appropriate Technology* options in the *Group Development Projects* at the University of Nottingham[40] and *Developing Technologies* at Imperial College London[41].

- ***Large-scale integrated projects***: a number of highly-regarded schemes are in operation whereby one overarching challenge is set to the full student cohort and each individual group is asked to tackle one aspect/element of the overall problem. Groups must work on their component/element on the understanding that, on completion, it must integrate together with the outputs of each of their peer groups to form a functioning design/product/process. One particularly well-regarded example is the group design project in the *Aerospace Vehicle Design MSc* at Cranfield University[42] where the student cohort take a concept aircraft through to the detailed design phase. A highly-regarded international example is the AAUSAAT3 program[43] at Aalborg University, where students from across the university have designed, built and launched a working satellite.

- ***Industry-based experiences*****:** across the UK, many engineering schools offer immersive industry-based projects, where student groups are asked to solve real commercial problems. Such programs often demand high staffing levels to secure the industry engagement and ensure that all project experiences are meaningful and engaging for all students involved. Highly-regarded examples of such projects include the *Teaching Contract Scheme*[44] at Loughborough University.

---

[39] Young, A. An 'eco-house' learning and teaching environment to facilitate the development of sustainability literacy, a presentation at the *Ivan Moore Symposium in Engineering Education: Student Centred Learning in Small Groups*, January 2008 (www.engcetl.ac.uk/downloads/events/ivan_moore_symposium_jan08/andy_young.pdf)

[40] Web-site: *Appropriate Technology Research Project*s (www.engsc.ac.uk/downloads/awards/sustainability.pdf)

[41] Web-site: *Developing Technologies*, Imperial College London (www.developingtechnologies.org/)

[42] Undergraduate module: *Aircraft Design*, Aerospace Vehicle Design MSc, Cranfield University (www.cranfield.ac.uk/students/courses/page38027.jsp)

[43] Web-site: AAUSAT3, Aalborg University (http://www.aausat3.space.aau.dk/)

[44] Willmot, P., 2003. Introduction of Student Mentors into a Programme of Industry, International Conference on Engineering Education, Valencia, Spain 21–25 July, 2003.

5 Case studies of good practice

Outlined in this section are 7 UK case study examples of robust, potentially transferable approaches to engineering PjBL. The case studies were identified through a series of interviews with over 70 experts and practitioners in engineering education, PjBL and PBL, followed by a more detailed analysis by the author of the programs highlighted. Where possible, institution visits have been made to better understand the context and application of the case studies identified.

The key focus of the study was the identification of successful approaches to engineering PjBL that had the potential to be transferred and adopted 'out-of-the-box' at other institutions. In the identification of 'successful' and 'transferable' case studies, the following guidelines were adopted, requiring that, where possible, each example must:

- cater to relatively large cohort numbers – a minimum of 50 students per year;
- require relatively low set-up and on-going costs[+];
- not require any specialist knowledge/equipment/contacts/learning spaces to operate, outside that typically found within an engineering department;
- be highly regarded both within the institution (Heads of Department, Directors of Studies, faculty and students) and by the wider community (academic peers, education specialists etc.);
- offer a sustainable 'stand alone' module or group of modules– i.e. must not be dependant on a curriculum designed around PBL or PjBL;
- provide a carefully designed, robust model that incorporates an appropriate assessment procedure;
- demonstrate the successful achievement of the learning outcomes (if evaluation data available);
- provide a project task/context that is engaging for both students and staff.

For all case studies included in this section, the relevant module/unit leader has been interviewed as part of the study and has approved the 2-page description of their program.

- Case study 1: *Design and Manufacture*, School of Mechanical and Systems Engineering, Newcastle University
- Case study 2: *Materials with Forensics*, Department of Materials, Queen Mary, University of London

[+] The maximum annual operational costs for each of the case studies presented (outside faculty/staffing time) does not exceed £15 per student per year.

- Case study 3: *Technology Strategy and Business Planning*, Department of Mechanical Engineering, University of Sheffield
- Case study 4: *Integrated Approaches to Sustainable Development*, University of Manchester
- Case study 5: *Materials, Manufacturing and Environmental Engineering*, Faculty of Arts, Computing, Engineering and Sciences, Sheffield Hallam University
- Case study 6: *Communication Systems 1, Department of Electronic and Electrical Engineering,* University College London
- Case study 7*: First Year Team Project,* School of Computer Science, University of Manchester

Provided in the table below is a summary of the case studies of UK best practice presented in this report. The table highlights a number of the pertinent aspects of the case studies: which year group is targeted, the cohort size (from the 2008/09 academic year) and whether the activity incorporates a 'hands-on' element.

Program/course	**Year of study**				**No. of students**	**Hands-on element**
	1	**2**	**3**	**4/MSc**		
1. *Design and Manufacture*, Newcastle Uni.		✓			94	✓
2. *Materials with Forensics*, Queen Mary Uni.	✓				60	✓
3. *Technology Strategy*, Uni. Sheffield				✓	110	
4. *Sustainable Development*, Uni. Manchester			✓		93	
5. *Mat., Manu. & Env. Eng.*, Sheffield Hallam	✓				80	✓
6. *Communication systems 1*, UCL	✓				70	✓
7. *First year team project*, Manchester Uni.	✓				250	✓

As discussed in Section 1.2, although the study has focused on the UK, many of the approaches developed in Australia in recent years were felt to be highly relevant to the overall study goals. Therefore a small number of highly regarded case studies from Australia have also been included in Appendix B.

5.1 Case study 1: Newcastle University

***Title**: Design and Manufacture*, School of Mechanical and Systems Engineering

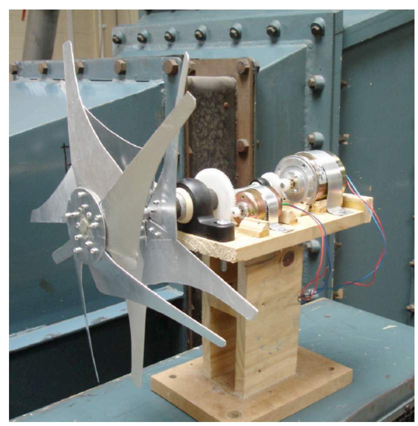
***Reasons for selection**: this case study from Newcastle University offers a low-cost design/build exercise within a context of domestic scale energy generation that is clearly motivational to the students involved. The exercise also requires minimal set-up costs or additional equipment requirements, so provides a relatively transferable model.*

5.1.1 Overview of Program

Design and Manufacture is a mandatory 15 credit module for second year Mechanical Engineering students at Newcastle University, operating over 2 semesters. The module has been developed and improved over the past 4 years, and has seen very positive feedback from the students involved. During the first semester, student groups are asked to design and build a domestic scale wind turbine using only the parts from a redundant computer and printer. During the second semester, each group is given a small budget and asked to improve on and develop their designs. The module contains 4 timetabled hours per week – a one-hour lecture and a three-hour practical design session.

Example of completed wind turbine from Semester 1

Design and Manufacture opens within a traditional lecture, to introduce students to the context of sustainable energy and discuss the various options for alternative energy generation. Students, working in groups of around 7, are then given a brief to design and build a domestic energy device using only the parts from a redundant computer and printer, which are provided. Groups are given a set of hand-tools with which to manufacture their turbine, as well as access to technician support for the production of any more complex items. At the end of the semester, the power output from the turbines is tested at three pre-defined wind speeds.



Example of completed wind turbine from Semester 2

During the second semester, each group is given a maximum budget of £100 and given a very open brief to '*improve their turbine in the most cost-effective manner possible'* - the final designs are tested on power output per pound spent. Most groups take this opportunity to substantially re-design their turbine, based on their observations and experiences during semester one.

5.1.2 Learning outcomes and assessment

The learning outcomes defined for the module include:

- *investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues;*
- *understanding of engineering principles and the ability to apply them to analyze key engineering processes;*
- *ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal;*

- *ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques;*
- *ability to apply quantitative methods and computer software relevant to mechanical and related engineering disciplines to solve engineering problems.*

In order to 'maintain the engagement of the students', significant levels of individual and group assessment are undertaken throughout the module, as summarized below.

1. A group essay to be submitted on 'wind turbine theory' in the first week.
2. At the end of semester 1, each group is assessed in 4 areas: the power output of the turbine, the design/build quality of the turbine based on a visual inspection by faculty supervisors, an interim 2-page report outlining the design/build exercise and a final group presentation.
3. At the end of semester 2, each group is assessed in 3 areas: the power output of the turbine per pound spent, the design/build quality of turbine, and a final report with engineering drawings either in the form of a video or a 3000 word document.
4. Each group must submit 7 weekly updates, detailing progress, challenges and other issues. Each group member takes responsibility for one of these progress reports.
5. All students keep a logbook throughout the project to detail their individual input to the exercise.

Throughout the project, students are encouraged to reflect on their own learning and development as engineers. For example, in the weekly update reports, students are asked to comment on their development against the learning outcomes for the module.

5.1.3 Operational information

Scale	The total cohort for the module in the current academic year (2009/10) is 94, with students working in groups of approximately 7.
Resourcing	The redundant computers and printers are sourced informally, at no cost. Budgets for semester 2 are £100 per group – around £1400 in total. Additional costs include kits of hand-tools for each group, which are reused every year.
Staff commitment	Three faculty members oversee the timetabled sessions, with additional support from 2 technicians during the 3-hour practical and in the manufacture of any specific items that cannot be produced with hand-tools.
Transferability	Such an exercise is low cost in both set-up and on-going requirements, and will easily cater to relatively high students numbers. Three additional requirements are: access to a wind tunnel, space for practical working and technician support.
Other issues	The assessment burden for the faculty members is relatively high.

5.1.4 Further information

- Joyce, T., 2009. A project-based learning Design course: experience, developments and assessment. *The Higher Education Academy Conference*, Manchester, UK 30 June–2 July 2009.

5.2 Case study 2: Queen Mary, University of London

***Title**: Materials with Forensics, Department of Materials*

***Reasons for selection**: this project is highly motivation for the students and encourages a detailed appreciation and working understanding of engineering experimental techniques. Students also learn about how to present often complex engineering ideas to non-engineering professionals. It represents a simple and fun example of PBL in the engineering curriculum that may help to engage unconverted faculty with this approach.*

5.2.1 Overview of Program

Over the past 10 years, the Department of Materials at Queen Mary, University of London (QMUL) has developed a PBL spine across the first and second year curriculum that accounts for a quarter of the course credits. Within the first year, the PBL element comprises 6 'case studies' that are linked to parallel lecture modules, delivering the supporting theoretical information.

A typical 'crime scene'

Hair under the microscope

The case study discussed here – *Materials with Forensics* - is a 3-week group project at the end of the first year that seeks to encourage a detailed understanding of the key engineering experimental techniques, as an alternative to more traditional 'laboratory experiments'. During this project, groups meet every other day for facilitated tutorials, and have access to four laboratories for experimental testing. The project is managed by one module leader and four teaching assistants oversee and facilitate all timetabled group meetings.

At the start of the project, students are confronted with a 'crime scene', for which they must provide expert witness testimony from the evidence collected. Each year, a new crime scene is staged containing trace evidence such as shards of glass, clothing fibers etc., typically in a vacant office space within the department. Each group is asked to investigate two pieces of evidence, one for the prosecution and one for the defense. For example, a group may be asked to identify whether a piece of glass found on the floor came from a broken window nearby.

Groups must first devise a plan of action for the safe extraction of their evidence, before being allowed to collect their samples from the scene. Each group then undertakes testing of their sample/s, analysis of the results obtained and preparation of their testimony. Through this testing and analysis process, students develop a working knowledge of a wide range of experimental techniques – such as Scanning/Transmission Electron Microscopy (SEM, TEM), Thermal Analysis (DSC, TGA, DMA), Infrared Spectroscopy (FTIR) and Energy Dispersive X-ray (EDX).

At the end of the project, a final 'court case' is constructed, with various faculty members acting as judge, council for the defense, council for the prosecution and the accused. Groups must submit their evidence in writing to the 'court' three days before the trial. In addition, one student from each group is nominated as the 'expert witness' to present their evidence in person at the hearing. Following this oral presentation, the expert witness is then cross-examined, not only about the evidence presented, but also their credibility as an expert in the field. This questioning is designed to test the students' understanding of experimental processes as well as the particular techniques/equipment used by that group. Through this 'cross-examination', a number of the expert witness statements are often dismissed, through lack of experimental rigor or the witness not holding sufficient expert knowledge in the field.

5.2.2 Learning outcomes and assessment

The full learning outcomes for the project are available elsewhere, but include:

- *to solve problems in an organized manner using brainstorming and resource investigation techniques;*
- *to build on prior knowledge and acquire new knowledge throughout the case study;*
- *to operate basic lab equipment (microscopes & mechanical testing machines) to support the case study investigations;*
- *to analyze and discuss experimental data using written reports, posters and oral presentations;*
- *to work in groups by managing group meetings and recording them using formal minutes to note all actions and decisions.*

Project assessment is conducted using input from the module leader, group tutors and individual students. The groups are assessed on their written 'submission' to the court and oral presentations of evidence for the 'court hearing'. Individual performance is assessed using a peer review process whereby each group member is assigned an 'individual scaling factor' by each of their team mates. The group tutor moderates these scaling factors, based on their observations of each individual's participation and performance.

5.2.3 Operational information

Scale	The total cohort for the module is 60, with students working in groups of 5.
Resourcing	The total annual project cost is £500. It is assumed that no new experimental equipment will need to be purchased for the project.
Staff commitment	One faculty member oversees the project, with additional faculty support for the final 'court case'. Four teaching assistants oversee all group discussions and technician support is typically required during testing processes. Additional input in the past has also included advice from London Metropolitan Police.
Transferability	Such an exercise is low cost in both set-up and on-going costs, and will easily cater to relatively high students numbers. It does require some 'creativity' in setting up the crime scene each year and devising evidence that will utilize the experimental equipment available.
Other issues	A suitable space is required for the staging the 'crime scene'.

5.2.4 Further information

Further information on the overall approach to PBL in the Department of Materials at QMUL is given at their PBL website[22].

5.3 Case study 3: University of Sheffield

***Title**: Technology Strategy and Business Planning, Department of Mechanical Engineering*

***Reasons for selection**: in recent years, a number of 'real world' engineering PjBL experiences have been developed in the UK that incorporate business planning with the competitive development of a new commercial product. In many of these approaches, the students are asked to deliver an 'elevator pitch' of their product idea to an expert panel during the final project assessment. This highly regarded example of such an approach has been recognized in a number of national awards[45] and its success is seen to have been instrumental in encouraging a greater acceptance of PjBL within the Engineering School of the host institution, Sheffield University.*

5.3.1 Overview of Program

The *Technology Strategy and Business Planning* module at the University of Sheffield is designed to introduce the '*concept, strategy, and techniques behind a business plan based on the exploitation or development of identified technological opportunities'*. The module is taken by final year students from across the engineering school, either as an elective or a mandatory requirement, depending on their degree specialism. Since its inception in 2002, the number of students enrolled on the module has gradually increased and stood at 110 in 2008/09.

Student groups are asked to develop solutions and an accompanying business plan for real commercial problems. In recent years, project briefs have focused on product concepts to improve the lives of real individuals or groups living locally. For example, in 2007, the project 'client' was a 7-year old boy with cerebral palsy who encountered a number of practical difficulties in his day-to-day life. Student groups were given a very open project brief of 'making life easier' for this child, and developed solutions ranging from writing supports to novel clothing. Each year, a different 'client' is selected, and this individual/s and their families work closely with the student groups throughout the semester-long module. The close involvement of these real 'clients' with the student groups and the potential for making a positive contribution to their quality of life are clearly strong motivators for the students involved.

The structure and relative time allocation for each element of the module is summarized below:

- traditional 'lectures' (25%);
- case studies and workshops (20%);
- presentations from external speakers (such as bankers customers, IP consultants and entrepreneurs) in areas such as 'Intellectual Property' (35%);
- support from research groups in the School of Engineering (10%);
- advice from a real mentor (10%).

The final deliverables at the end of the semester include:

- a report containing details of the product and accompanying business plan;
- a 80 second 'elevator pitch' of the product idea to a expert panel, followed by a detailed interview;
- a poster presentation, designed to attract potential funders to the product concept.

---

[45] Awards for the development of this module includes the *Royal Academy of Engineering, ExxonMobil Award in Excellence of Teaching 2008-2009* and the *HE Academy Engineering Subject Centre Teaching Award 2004-2005*

The combination of the business-orientated product development with a real and visible social impact has created significant media interest. Such media coverage is relatively uncommon in UK curricular engineering education and is seen as a valuable asset to the overall program profile and recruitment.

5.3.2 Module objectives and assessment

The module objectives are given below:

- *to develop the analytical and critical skills of final year students;*
- *to examine the role of technology in the business environment;*
- *to demonstrate the importance of having a structured business plan in the development of a commercial venture;*
- *to look at the components (resources, financial, marketing, IPR, etc) of the planning process and to introduce the tools and techniques of business planning;*
- *to demonstrate the use of these tools and commercial awareness by developing a business plan for exploiting or developing an identified technological opportunity.*

The final assessment of each group is conducted by a team of internal faculty, external industry experts and the project client/s. The assessment is group-based, and made on the basis of the *Business Plan* (40%), poster (40%) and a final discretionary mark (10%) allocated only for exceptional work. In addition, a £1000 prize is also allocated to the highest scoring team from the panel assessment of the presentations.

5.3.3 Operational information

Scale	Last academic year (2008-2009), 110 final year MEng students from across the engineering school enrolled in the module, typically working in groups of 3 or 4.
Resourcing	The set-up and operational costs for this module are very low and do not extend beyond the production of the posters presentations and hospitality for invited guests. All external partners are engaged on a voluntary basis. Each year, industry sponsors donate around £1000 as a prize to the winning project.
Staff commitment	One faculty member manages and delivers the full project. Additional internal faculty support is minimal and includes occasional specialist lectures and availability for advice to student groups on request. External involvement from industry experts is provided in specialist guest lectures and involvement in the final project delivery/assessment. Involvement from the selected 'client/s' is required throughout the project and in the final delivery/assessment.
Transferability	Such a project offers a stand-alone model that caters to relatively large cohort numbers with minimal costs. The constraints, however, lie in the ability of the module leader/s to access the required external industry specialists and to effectively identify and sensitively manage the relationship with the project 'client' each year.
Other issues	The most significant issue surrounding this project is ensuring the ethical management of the relationship the 'client' an ensuring that their expectations are in line with the likely project outcomes.

5.3.4 Further information

- Web-resource: *Embedding Enterprise in Engineering - Reality Teaching Through a Business Planning Module*, 2005. (www.engsc.ac.uk/downloads/entre.pdf)

5.4 Case study 4: University of Manchester

Title: *Integrated Approaches to Sustainable Development*

Reasons for selection: *this case study combines two areas of considerable current interest in UK engineering education: contextualizing sustainable development within the curriculum and providing students with meaningful interdisciplinary experience. Considerable care has been given to the design of the various project 'scenarios' employed throughout this pilot module as well as in the assessment regime and overall monitoring/evaluation process. The module was also developed with transferability in mind, with a view to replication in universities across the UK.*

5.4.1 Overview of Program

This case study describes a pilot development at the University of Manchester supported by the Royal Academy of Engineering's Visiting Professors Scheme (VPS). The pilot project at Manchester was designed to introduce engineering students to sustainable development within a multi-disciplinary context. A key focus of the program is to expose students to complex, ill-defined 'wicked problems' - '*working with other disciplines on 'wicked problems' gives students the confidence to work on difficult real-life problems in their lives beyond university and to be ready to 'make a difference' as change agents'*.

Five years of research, development and discussion were undertaken before the first pilot phase of the project was rolled out in 2006. The module structure, context and implementation were informed by a senior-level steering committee and four advisory groups of faculty from across the engineering school. To date, three multi-disciplinary student cohorts have enrolled in the module - 48 students participated in 2006/07 from across four engineering departments, 93 students participated in 2007/08 from a number of engineering disciplines as well as Chemistry, Computer Science, Mathematics and Physics and, in 2008/09, 96 students from a broad range of disciplines participated, including Geography and Life Sciences.

The module – *Integrated Approaches to Sustainable Development* – is an elective operating in the final semester of the 3rd year. Throughout the 12 weeks, multi-disciplinary groups of around 8 students work in sequence on 5 project scenarios, each operating in a 2-3 week cycle. Each of these projects is carefully designed as a '*sequence of student-centered, contextual, integrated, active, collaborative and reflective learning opportunities'*. Typical project outputs would be in the form of a report to the local council, a presentation to a scientific committee or an information leaflet for the public. The project scenarios given to the groups are designed to be 'cumulative', such that the students build on their knowledge, experience and skills through the module. Much of the summative assessment is therefore focused on the final 3-week exercise, although each exercise is also formatively assessed.

Each project task is devised, presented to the student groups and assessed by an expert in the field – 'lead authors' have included architects and layers as well as engineering discipline experts. A typical project scenario, taken from the 2007-08 pilot, is summarized below.

> *Recommend steps for engaging with the public and other stakeholders regarding construction of a new PVC recycling facility, in the North West UK. Having identified the key controversial issues surrounding the suitability and safety of PVC as a material, presenting this to the public in a clear and balanced way using the format of a short information leaflet.*

Each group is assigned with a dedicated 'facilitator', typically a Post-Doctoral Research Assistant, to support the group working. The facilitators are given two two-hour sessions of training before the commencement of the module, to introduce the project, the PBL model and how to approach group facilitation. Facilitators are present for the weekly two-hour meetings of their assigned team, as well as a one-hour debrief following the group meetings to '*further the facilitators' learning, to allow the project* *team to keep in touch with what was happening in the groups and to provide briefing for subsequent exercises'.*

5.4.2 Learning outcomes and assessment

A number of different assessment processes were trialed during the 2-year pilot phase. Based on feedback from both students and faculty, the following 3-stage summative assessment regime was agreed:

- individual reflective report – including a reflective log for each of the 5 'scenarios' (60%);
- group project submission for the final 'scenario'(40%, moderated by peer assessment);
- peer assessment for the final 'scenario' – an anonymous check-sheet is competed by all students relating to each of their fellow group-members.

The full learning outcomes defined for the module are listed in the appendices to the report referenced below, along with further details of the assessment regime.

5.4.3 Operational information

Scale	In 2008/09, 98 students enrolled on the module, working in teams of 8. It is anticipated that 200 students will enroll during the current academic year (2009/10).
Resourcing	The development and management costs for the first two years of the initiative were funded by a £35k pa grant from the Royal Academy of Engineering, through their Visiting Professors scheme. Staffing represents the majority of on-going costs.
Staff commitment	During the project pilot, the on-going staffing requirements included a project manager, a project-support officer, 12 facilitators and 5 'lead authors'.
Transferability	The model appears to be transferable. Two key issues for successful implementation include the identification of suitable case study scenarios and the timetabling of the multi-disciplinary teams, taking students from across different schools.
Other issues	Although designed with significant thought, the pilot phase for this module has only recently been completed, and, as such, its long-term sustainability is not proven.

5.4.4 Monitoring and evaluation

Throughout the 2-year pilot phase, the module was monitored and evaluated in terms of its overall acceptability, effectiveness and sustainability. Feedback was gathered through a range of means, including the facilitators de-briefing sessions, student self-perception questionnaires (at the beginning and end of the module) and the nominal group technique for the full cohort.

5.4.5 Further information

As the module has been specifically developed with transferability in mind, detailed accompanying material has been prepared, providing information on most aspects of its design and implementation. The final project report[46] and accompanying appendices provide information on areas such as the assessment processes, the 'scenarios' given to the students and the overall module monitoring/evaluation.

[46] *Educating Engineers for Sustainable Development: final report of a Royal Academy of Engineering sponsored pilot study*, University of Manchester, Faculty of Engineering and Physical Sciences, March 2009 (http://www.eps.manchester.ac.uk/tlc/sd/)

5.5 Case study 5: Sheffield Hallam University

Title: *Materials**,** Manufacturing and Environmental Engineering, Faculty of Arts, Computing Engineering and Sciences*

Reasons for selection*: Although only implemented, to date, as a two-year pilot, this module has had a significant impact on the use of media in engineering education throughout the UK. The module, which asks students to make short videos on technical engineering topics, develops the students' ability to work autonomously and communicate effectively to professional non-engineering audiences. The experience also incorporates an end-of-module conference, which clearly both engages and focuses the students.*

5.5.1 Overview of Program

The *Materials**,** Manufacturing and Environmental Engineering* module was developed over a 5 year period and seeks to develop greater levels of 'learner autonomy' in engineering students. The module was implemented as a pilot in 2007/08 in partnership with the *Centre for Promoting Learner Autonomy* at Sheffield Hallam University and is anticipated to be fully integrated into the curriculum in 2010/11. By the end of this 2-semester module, student groups must devise and deliver a short video to be presented in a professional conference environment. The module comprises 2 timetabled hours per week, with an expectation that additional group working will be conducted independently. During semester 1, students are introduced to team-working concepts and the practice of video-production through a series of key-note lectures, laboratories, tutorials and drop-in sessions. During semester 2, groups are presented with their project 'scenario' and provided with additional support and instruction in the use of video production and editing software.

Student groups filming 'content'

Final 'conference' presentation

During the pilot phase of the module, the student cohort was divided into two halves, and each provided with a slightly different problem scenario - one half was asked to produce short video clips to describe a particular manufacturing process, while the other half was asked to source video to illustrate the causes of an 'engineering disaster'. It is anticipated that, when this module is integrated into the curriculum next year, these briefs will be combined and all student groups will be given the following problem scenario - *to make and source video to illustrate the causes and potential solutions to a real engineering disaster*.

Towards the end of semester 2, all student groups are asked to develop and deliver a conference presentation that incorporates their video clips. This final conference is designed as a formal professional engineering event, held in a venue outside the department, with external invited guests and a specialist keynote speaker from industry.

5.5.2 Module aims and assessment

The aims of the module are defined as:

- *to develop learner autonomy with first year engineering students;*

- *to link individual critical review of knowledge and skill development of the students and relate this to their Personal Development Planning (progress files) through the use of group project learning;*
- *to encourage students to work effectively in teams and independently to develop both communication and presentation skills, as well as engineering problem solving skills through enquiry;*
- *to use digital media technology to enhance student learning;*
- *to develop innovative teaching methods for staff;*
- *to reduce the burden of assessment on both staff and students.*

The assessment load is relatively small, and comprises 2 elements:

- group presentations at the end-of-module conference, which are assessed by a panel of faculty and external industry partners. No peer assessment is employed and no written reports are submitted.
- individual multiple-choice test, held at the end of the semester, a few weeks after the conference. The test is based on the information delivered both during the module and within the conference presentations, and is designed to increase the student engagement with the presentations of their peer groups.

5.5.3 Operational information

Scale	The module caters to around 60-80 first year students, working in groups of 5.
Resourcing	The major cost associated with the module is the purchase of the cameras. In the future, one *Flip Video Camcorder* will be purchased for every two teams, at a cost of around £100 each. Student groups utilize the video editing software available as standard on most computers, such as *imovie* and *Windows Movie Maker*. Additional costs include room hire and catering for the final conference.
Staff commitment	Two module leaders designed and manage the activity. Additional support is also engaged for tutoring students in key skills such as project management, presentation skills and conflict resolution. An industry expert presents the keynote lecture at the conference.
Transferability	The model is relatively transferable, with low staffing requirements and assessment loads. Once cameras have been purchased, set-up and on-going costs for this experience are relatively low.
Other issues	Some in-house expertise in filmmaking and editing would be highly beneficial, although not essential, for the support of the student groups. As a module developed in recent years, the long-term viability and success of this experience has not been proven.

5.5.4 Further information

- Web-resource: First & Final Year Experience in Materials Engineering, 2009 (https://extra.shu.ac.uk/cetl/cpla/casestudies.html)
- Bramhall, M., 2008. Users as Producers: students using video to develop learner autonomy, Engineering Education 2008, Loughborough University, England 14 -16 July 2008.

5.6 Case study 6: University College London (UCL)

Title: *Scenario C: Transistor Radio Kit, Department of Electronic and Electrical Engineering*

Reasons for selection*: a number of intensive full-time PBL 'scenarios' have been implemented into the first and second year of the curriculum in the Department of Electronic and Electrical Engineering at UCL. Almost without exception, the UK education professionals consulted during this study rated these developments at UCL as the most carefully designed and successful examples of PBL that they had seen in UK engineering programs.*

5.6.1 Overview of Program

As discussed in Section 3.2, PBL has been adopted in a number of 1st and 3rd year modules in the undergraduate programs in the *Department of Electronic and Electrical Engineering* at UCL. Within the UK, intensive PjBL/PBL projects are typically seen during the first-year induction or in the final year of the curriculum, but such full-time experiences are much less common between these times.

The first year of the *Electronic and Electrical Engineering* program has recently been restructured around 5 week cycles, which culminate in a full-time one-week PBL 'scenario'. During these scenarios, groups are provided with a problem brief, typically involving a hands-on element, such as to develop an airport identity recognition software system or compete in an electromagnetic weight-lifting competition.

The scenario described here is the development of a transistor radio kit to be constructed and used by children in the developing world. Groups are provided with the following problem scenario on the first morning of the week-long exercise, from which they must design and construct a working prototype:

> *You work for an electronics design consultancy based in London. You have been approached by an organization that sends educational science kits to high school students in emerging nations. They have asked you (and several other similar consultancies) to design a radio kit that can be built by students with the simple resource they might have available. The kits needs to be both a fun and exciting project for the students to build, but should also give them in the end a reliable radio that they can actually use in their homes.*

In line with this brief, groups are given a number of constraints for their designs - for example, the kit must not require specialist tools for its construction (such as soldering equipment), the design must demonstrate compatibility with alternative power sources as well as battery power, and, once constructed, the radio must allow families to listen to distant rural radio stations.

Once the problem has been defined, groups must assign individual roles for each group member and identify a work plan for the week. Although groups work largely independently, in line with their project plan, facilitation sessions are scheduled regularly throughout the week and the departmental laboratory is made available for two afternoons. On the final afternoon, groups must present a working prototype of their design with an accompanying poster presentation.

5.6.2 Learning outcomes and assessment

The overall module 'scenarios' are designed to

- *bring together the material presented in across the lecture modules;*
- *further student learning by application of the theoretical concepts introduced in lectures;*
- *increase real world applicability of the students' knowledge, which may even include industrial sponsorship and involvement in scenarios.*

In terms of *learning outcomes*, the scenarios are designed to enable students to:

- *develop an intuitive understanding of what they're being taught;*
- *become aware of how useful the lecture material is;*
- *stop seeing the lecture material as an set of unconnected details;*
- *learn how to carry out a research/design project including how to search literature effectively.*

Formative assessment for the ‘transistor radio kit’ scenario comprises 3 elements:

- a group poster and prototype showcase, to be presented on the afternoon of the final day. The poster must present the *technical merit, cost, innovation and practicality* of the design.
- an individual report to be submitted during the week following the scenario. Each student is asked to make a critical assessment of the design produced by one other team and compare this solution to their own group’s design. This component has been included, in part, to ensure that students engage fully with the work of peer groups during the showcasing presentations.
- an individual reflective journal, updated throughout the week.

The working prototype, group poster and individual report are summatively assessed.

5.6.3 Operational information

Scale	The first year compulsory module caters to a cohort of 50-70 students, working in groups of 4.
Resourcing	The experience is designed around standard components and simple equipment that are available within typical electrical engineering laboratories. The only additional components purchased for the scenario are specialist inductors. Total set-up costs are less than £50. Both set-up and on-going costs are therefore low.
Staff commitment	The module is managed by four faculty members, who oversee all activities including the laboratory sessions. It has been acknowledged that staffing levels could be reduced without any compromise to the student experience.
Transferability	Such an experience is highly-engaging for the participants, could be scaled-up to support larger cohort numbers and is relatively low-cost.
Other issues	In its current form, this experience requires a dedicated week in the curriculum to be secured.

5.6.4 Further information

A number of publications are available on the more general PBL developments in the *Department of Electronic and Electrical Engineering*, including:

- Mitchell, J. E. and Smith, J., 2008. Case study of the introduction of problem-based learning in electronic engineering, *International Journal of Electrical Engineering Education*, 45(2), 131-143.

5.7 Case study 7: University of Manchester

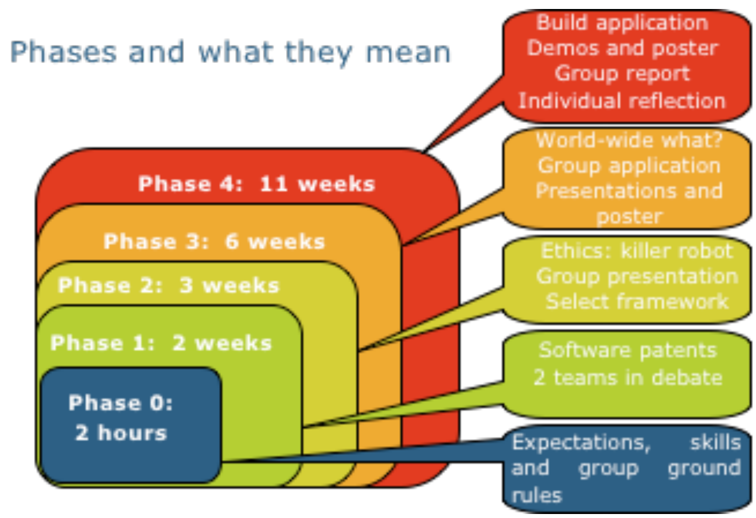
Title: *First Year Team Project, School of Computer Science*

Reasons for selection*: this highly-regarded module was developed in partnership with the Centre of Excellence in Enquiry-Based Learning (CEEBL) at the University of Manchester. The module uses a structured approach to gradually introduce first-year students to project-based learning (PjBL) and has been designed to build their confidence in approaching open-ended self-directed problems. A number of interviewees in the study have commented on the quality of both the module design as well as the final projects delivered by the student groups.*

5.7.1 Overview of Program

The *First Year Team Project* in the School of Computer Science was first implemented in 2006/07 in response to concerns about the students' ability and desire to work independently. This new 'self-directed learning' module was designed to establish a different attitude to teaching and learning amongst the students from the start of their studies. The compulsory 20-credit module caters to 250 first years and runs throughout the academic year. Timetabled classes include a weekly one-hour group tutorial for the development of personal and professional skills, a weekly one-hour lab for individual skills development and occasional guest lectures on topics such as *project management*. The final module deliverable is a '*database driven web application, defined, designed, built and marketed by the group*'.

The module is structured to gradually introduce the students to the concepts of PjBL, through providing a series of open-ended problem scenarios of increasingly complexity and duration while offering decreasing levels of support. Throughout the experience, students are provided with no technical instructional information and are expected to source all information required for solving the problems independently. The 5 phases of this structure are summarized below.



- **Phase 0 (2 hours):** these 'ice-breaker' activities are designed to help to bond the newly-formed group. Tasks include making an audit of group skills, identifying a 'group motto' and establishing the on-going ground rules for the group's activities.
- **Phase 1 (2 weeks)**: groups are asked to look at the issues surrounding software patents, and must divide into two teams of 3 for a debate on a topic in the area.
- **Phase 2 (3 weeks):** groups are asked to identify and reflect on different ethical frameworks for decision-making, and apply these to a complex hypothetical 'scenario'.
- **Phase 3 (6 weeks):** following an investigation of the World Wide Web, student groups are asked to develop a concept for a new database driven web-application, along with an associated project management plan for their upcoming design and build phase (Phase 4). The deliverable for Phase 3 is an oral and poster presentation of the group's design and plan.
- **Phase 4 (12 weeks):** during the final 12 week phase, the groups are asked to build their web application and provide an oral presentation and report on the design and development process. All

web-applications are also demonstrated through a 'project showcase day'. Finally, each student is asked to deliver an individual report on the development process.

5.7.2 Learning outcomes and assessment

Students who successfully complete this module will:

- *be able to better understand the difference between what is ethical and what is legal;*
- *be aware of the requirements for professionalism in respect of the work of the professional societies and their codes of conduct and practice;*
- *have a basic knowledge of relevant legal issues, such as contracts, IPR, and computer mis-use;*
- *have improved knowledge and some experience of group working;*
- *have acquired presentation skills;*
- *be aware of some of the potential problems of managing large IT projects.*

The module assessment comprises 5 elements (not equally-weighted):

- tutors and demonstrators assign a mark (on a simple 4-point scale) to all group members on a weekly basis, based on their contribution to the group's activities;
- group essay in Phase 2 on ethical frameworks;
- group oral and poster presentation from Phase 3, moderated by peer assessment;
- group oral presentation and written report from Phase 4, moderated by peer assessment;
- individual report from Phase 4.

5.7.3 Operational information

Scale	The typical cohort number is 250. Students work in groups of 6, comprising a mix of genders, background and abilities.
Resourcing	Outside the relatively intensive staffing requirements, see below, the costs associated with this module are relatively low and would not extend beyond production of the final poster presentations.
Staff commitment	The module is managed by two faculty 'leaders'. Around 40 faculty tutors are engaged for group facilitation during tutorials (one per group), and around 12 graduate students act as 'demonstrators' during the weekly labs. A small number of external speakers are engaged for occasional lectures.
Transferability	The phased structure of the module would provide a transferable framework for faculty who were not familiar with managing PjBL experiences. Probably the most significant issue is the number of faculty required for group facilitation and supervision. The assessment burden is also relatively high.
Other issues	A VLE (*Moodle*) is used to support the module in areas such as information repository, discussions forums and provision of wikis. Additional resource is required to maintain the VLE installation throughout the year.

5.7.4 Further information

- A presentation describing the module from May 2009, entitled '*Introducing Enquiry Based Learning into the First Year Computing Curriculum*', given at a UK workshop. (www.campus.manchester.ac.uk/ceebl/events/archive/largecohorts/ceebl-talk.pdf)

6 Concluding comments

PjBL, is a growing area of interest within engineering education in the UK, with a wide variety of experiences integrated into the undergraduate education in universities across the country, both within and outside the curriculum.

The study has highlighted a range of good practice approaches to engineering PjBL in the UK. Of the examples presented, the case study from Queen Mary, University of London (see Section 5.2) offers a particularly interesting model for transfer. This example provides a carefully designed and low-cost alternative to more traditional '*engineering labs'*. The example is also highly engaging, and its introduction may help to enthuse unconverted faculty to the benefits of PjBL within the engineering curriculum.

However, despite keen interest in the PjBL approach, there are a number of barriers that inhibit its wider integration within the UK engineering curriculum. Overall, four key areas of concern exist– *assessment*, *evaluation, resourcing* and *sustainability*, as discussed below.

- There is clearly a lack of confidence and knowledge amongst a number of UK engineering faculty in the design and application of student *assessment* processes in PjBL. For this reason, perhaps, many PjBL experiences are highly structured and employ a wide range of different summative assessment processes within the single activity, with a resulting high workload for both staff and students.
- Outside mandatory 'student satisfaction surveys', very few UK engineering PjBL activities conduct rigorous *evaluations* of the experience. If greater levels of support/advice could be provided for module leaders to undertake such evaluations, the resulting data, if shown to have a positive impact, may help with the greater integration of PjBL activities in the future.
- *Resourcing* has been identified as a significant barrier for the adoption of new PjBL experiences. PjBL was identified by many faculty as one of the most resource-intensive elements of the current engineering curriculum, often demanding tailored learning spaces, materials, tools and equipment as well as requiring significant time from faculty and support staff. The imminent closure of a number of the England-wide *Centers for Excellence in Teaching and Learning* in 2010 and the recently-announced government cuts to university funding are expected to result in a further reduction in the funding for engineering education, which may impact future developments in PjBL. In this context, the engineering education communities/networks in the UK are likely to play an ever more important informal role in inspiring and supporting faculty in the greater use of PjBL in the curriculum.

- In line with many initiatives of this kind across the world, *long-term sustainability* is probably the most significant area of concern within UK engineering PjBL. The majority of PjBL activities operate in relative isolation within their departments and are typically driven forward by a small number of passionate ‘champions’ with limited support from internal senior management or external bodies. Many such initiatives in their current application, therefore, are unlikely to be sustained and/or developed beyond the tenure of the module leader. A small number of UK institutions - most notably, in recent years, the *Faculty of Engineering and Computing* at Coventry University and the *Department of Civil, Environmental and Geomatic Engineering* at UCL – are undertaking more extensive and structured re-designs of their undergraduate education that incorporate significant PjBL activities. Although these initiatives are currently at an early stage, the institutions have developed new models for the sustainable support of PjBL activities and, as such, are likely to play a future role in driving forward the integration of such activities in the engineering curriculum across the UK.

Appendix A. Individuals interviewed/consulted

A.1. United Kingdom

Alison Ahearn	Lecturer in Construction and Education Engineering, Faculty of Engineering, Imperial College
Esat Alpay	Senior Lecturer in Engineering Education, Faculty of Engineering, Imperial College London
Carol Arlett	Centre Manager, Higher Education Academy Engineering Subject Centre, Loughborough University
Howard Ash	School of Engineering and Technology, University of Hertfordshire
Mike Barnes	Senior Lecturer, School of Electrical and Electronic Engineering, University of Manchester
Marjahan Begum	Research Associate, Engineering Centre for Excellence in Teaching and Learning (engCETL), Faculty of Engineering, Loughborough University
Jim Boyle	Head of Department, Mechanical Engineering, University of Strathclyde
Roger Boyle	Professor of Computing, School of Computing, University of Leeds
Mike Bramhall	Head of Teaching, Learning and Assessment, Faculty of Arts, Computing Engineering and Sciences, Sheffield Hallam University
James Busfield	Reader in Materials, School of Engineering and Materials Science, Queen Mary, University of London
Grant Campbell	Reader, School of Chemical Engineering and Analytical Science, University of Manchester
Brian Canavan	Lecturer, Educational Studies, University of Glasgow
Mark Childs	Teaching Development Fellow, Centre for the Study of Higher Education, Coventry University
Robin Clark	Head of Learning and Teaching Research, CLIPP, Aston University
Geoff Cunningham	Director of Education, School of Mechanical and Aeronautical Engineering, Queen's University Belfast
Adam Crawford	Manager, Engineering Centre for Excellence in Teaching and Learning, Loughborough University
Claire Davis	Reader, School of Metallurgy and Materials, University of Birmingham
Ian Dunn	Associate Dean (External), Faculty of Engineering and Computing, Coventry University
Lewis Elton	Honorary Professor of Higher Education, Centre for the Advancement of Learning and Teaching, University College London
Charles Engel	Visiting Professor, University of Manchester
Marco Federighi	Faculty Tutor and Sub-Dean of Engineering Sciences, University College London
Sally Fincher	Professor of Computing Education, School of Computing, University of Kent

Arthur Garforth	Director of Undergraduate Studies, Department of Chemical Engineering, University of Manchester
Peter Goodhew	Director of the UK Centre for Materials Education, Department of Engineering, University of Liverpool
Graham Gough	Director of the Undergraduate School, School of Computer Science, University of Manchester
Tom Joyce	School of Mechanical and Systems Engineering, Newcastle University
Fred Maillardet	Chairman, Engineering Professors Council and Former Dean of the Faculty of Science and Engineering, University of Brighton
Omar Matar	Director of Undergraduate Studies, Department of Chemical Engineering, Imperial College London
Andrew McLaren	Director of Studies, Department of Mechanical Engineering, University of Strathclyde
John Mitchell	Senior Lecturer in Telecommunications, Department of Electronic and Electrical Engineering, University College London
Ivan Moore	Director, Centre for Promoting Learner Autonomy, Sheffield Hallam University
Matt Murphy	Engineering Education Development, Department of Engineering, University of Liverpool
Karen O'Roarke	Academic Developer, Institute for Enterprise, Leeds Metropolitan University
Roger Penlington	Teaching Fellow & CETL Fellow, School of Computing, Engineering & Information Sciences and CETL Assessment for Learning, Northumbria University
Norman Powell,	Research Associate, Centre for Excellence in Enquiry-Based Learning, University of Manchester,
Richard Prager	Deputy Head of the Engineering Department (Teaching), University of Cambridge
Derek Raine	Senior Lecturer, Department of Physics and Astronomy, University of Leicester
Stephen Richardson	Principal, Faculty of Engineering, Imperial College London
Elena Rodriguez-Falcon	Senior University Teacher, Department of Mechanical Engineering, University of Sheffield
Gaynor Sadlow	Assistant Head of School, School of Health Professions, University of Brighton
Maggi Savin-Baden	Director, Learning Innovation, Coventry University
Judith Shawcross	Centre for Technology Management, Institute for Manufacturing, University of Cambridge
James Shuttleworth	Associate Head, Computing and the Digital Environment, Faculty of Engineering and Computing, Coventry University
Elizabeth Smith	Faculty Support Manager, Faculty of Engineering and Computing, Coventry University
Jan Smith	Lecturer, Centre for Academic Practice & Learning Enhancement, University of Strathclyde

Simon Steiner	Academic Advisor, Engineering Subject Centre, Loughborough University
Melanie Thody	Head of Outreach and Director of Access, Imperial College London
Bland Tomkinson	University Adviser on Pedagogic Development, University of Manchester
Rosemary Tomkinson	Academic Development and Innovation Advisor, University of Manchester
Nick Tyler	Head of Department and Professor of Civil Engineering, Department of Civil, Environmental and Geomatic Engineering, University College London
Peter White	Associate Dean, Faculty of Engineering and Computing, Coventry University
Peter Willmot	Principal University Teacher, The Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University
Sarah Wilson-Medhurst	Teaching Development Fellow, Faculty of Engineering and Computing, Coventry University

A.2. Rest of the world

Lyn Brodie	Lecturer, Faculty of Engineering and Surveying, University of Southern Queensland
Lizzie Brown	Director of Education, Training and Research, Engineers Without Borders Australia
Ian Cameron	Senior Fellow, Australian Learning & Teaching Council and Professor, Chemical Engineering, University of Queensland
Duncan Campbell	Alternate Head of School, School of Engineering Systems, Queensland University of Technology
Jens Dalsgaard Nielsen	Associate Professor, Department of Electronic Systems, Aalborg University
Gavin Duffy	Lecturer, School of Electrical Engineering Systems, Dublin Institute of Technology
Anne Gardener	Senior Lecturer, Faculty of Engineering, University of Technology, Sydney
Roger Hadgraft	Director, Engineering Learning Unit, Melbourne School of Engineering
Brent Jesiek	Assistant Professor of Engineering Education, Department of Engineering Education, Purdue University
Lesley Jolly	Strategic Partnerships, University of Queensland
Patrick Keleher	Associate Dean, Engineering and the Built Environment, Central Queensland University
Euan Lindsay	Senior Lecturer, Department of Mechanical Engineering, Curtin University of Technology
Julie Mills	Associate Professor and Program Director in Civil Engineering School of Natural and Built Environments, University of South Australia
Gillian Saunders	Chair of Aerospace Structure, Faculty of Aerospace Engineering, Delft University of Technology
Trudy Schwartz	Senior Instructor, Lab Manager, Electronics and Instrumentation Lab, University

	of Colorado
Mark Somerville	Associate Professor of Electrical Engineering and Physics, Franklin W. Olin College of Engineering
Johannaes Strobel	Assistant Professor, Engineering Education & Educational Technology, Purdue University
Sarah Symons	Assistant Professor, Integrated Science & Dept. of Physics and Astronomy, McMaster University
Yevgeniya Zastavker	Associate Professor of Physics, Franklin W. Olin College of Engineering

Appendix B. Australian case studies

Although this report is primarily focused on engineering PjBL activity in the UK, a number of additional Australian-based examples of best practice were also identified in the study. As this is the first report in a series of international studies in engineering PjBL, it was felt important to highlight and document any other examples of good practice that were available at this stage. Three case studies of engineering PjBL best practice from Australia are therefore included in this Appendix:

- Case study A1: *EWB Challenge*, Engineers Without Borders Australia
- Case study A2: *Civil Engineering Design Project*, Civil Engineering Department, University of South Australia
- Case study A3: *Engineering Foundations: Principles & Communications*, Curtin University of Technology

For all case studies included, the relevant module/unit leader has been interviewed as part of the study and has approved the 2-page description of their program.

B.1. Australian case study 1: Engineers Without Borders Australia, Australia

Title: *EWB Challenge*

Reasons for selection*: this highly-regarded program offers a model whereby an 'out-of-the-box' project-based learning experience is developed centrally and offered at a national level to a large number of institutions. The on-going central operational costs for this semester-long program are also relatively low – equivalent to around $14 (US) per student per year.*

Overview of Program

The *EWB Challenge* is a '*national design program for first year university students…providing the opportunity to learn about design, sustainable development, team work and communication through real and inspiring sustainable development projects'*. The project, currently in its third year of operation, is managed centrally by Engineers Without Borders Australia (EWBA) in partnership with 26 universities across Australia and New Zealand.

Each year, EWBA works with their international partners to identify and develop an appropriate set of design briefs for the first-year student teams. The 2009 *Challenge* focused on supporting disadvantaged communities based around the Tonle Sap Lake and River in Cambodia, providing 7 project briefs on broad themes such as '*water and sanitation'* and '*transport'*. Alongside the project briefs, EWBA also supply universities with a suite of resources and support for setting these 'challenges' to their first year design students, such as a monthly e-newsletter, maps and a virtual tour of the project site. They also offer one-to-one 'training' for the module leader/s to provide further details on the project briefs and their local community contexts and also familiarize them with the additional resources available. It is acknowledged that involvement with this program considerably reduces the typical workloads of module leader/s in the development, delivery and support for such large-scale first year design projects. Although universities are individually responsible for their own student assessment, some chose to adopt the central *EWB Challenge* judging criteria, which again reduces the overall time commitments considerably.

At the end of the semester, student teams are asked to submit a detailed design report that includes specifications such as product construction, operation, maintenance as well as issues of context, ethics and sustainability. Students are also asked to reflect on and document their learning experience. On completion of the *Challenge*, each university nominates up to four teams for external judging, from which six overall winning teams are selected at a national level.

Although a relatively new initiative, the *EWB Challenge* already has a strong international reputation, and a number of the partner universities would point to this element of their curriculum as being one of their most successful project-based learning experiences.

Learning outcomes and assessment

The *Challenge* is designed around the development of 4 of the 10 graduate attributes required by the Australian accrediting body, Engineers Australia. These targeted attributes are:

- *understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;*
- *understanding of the principles of sustainable design and development;*
- *understanding of professional and ethical responsibilities and commitment to them;*
- *ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams.*

Operational information

Scale	The program currently caters to around 7000 students across 26 universities. The largest single student cohort is 1300, at Queensland University of Technology, but typical cohort numbers are closer to 700. Students typically work in groups of 4.
Resourcing	The 2009 central EWBA budget for the project was $130K AUS. Although participating schools are asked to contribute $1K AUS, the majority of funding is sourced through external sponsorship. EWBA employs a full-time coordinator for the *Challenge*, and, at most universities, unpaid EWB member groups support the project delivery through, for example, becoming module tutors or running relevant workshops.
Staff commitment	EWB staffing: one full-time coordinator and a local coordinator at each institution Institutional staffing: each institution manages and delivers the instruction and supervision associated with the project. Typically, three tiers of staffing are employed, with the module leader/s overseeing the project and year group, faculty supervisors overseeing a number of student groups and tutors directly delivering much of the material to the student teams and supervising progress.
Transferability	Such a model is highly transferable, with the *Challenge* currently being adopted by a large number of different institutions across a range of student abilities.

Impact assessments and program developments

One overall area of concern with the program, current being addressed, is ensuring that the quality of information provided to each university module leader is effectively filtered down to the students. EWBA have observed that important material is sometimes lost as information is conveyed through the various supervision layers of module leaders, faculty supervisors, module tutors and through to the students. For this reason, plans are in place for 2010 to hold regional training workshops for all participating faculty/staff with a supervisory/support role.

A research project is currently underway at the University of Queensland looking at the impact of the *EWB Challenge* on the student learning experience. Due to be completed in September 2010, the provisional findings suggest that student expectation, cohort size, disciplinary specialization and project integration are all important factors in the success of such an initiative.

Further information

- Jolly, L., Crosthwaite, C., Brown, L., 2009. A Program Logic Approach to Evaluating Educational Innovations, Proceedings of the Research in Engineering Education Symposium 2009, Palm Cove, QLD
- More general information is also available at the EWB Challenge website (www.ewb.org.au/ewbchallenge)

B.2. Australian case study 2: University of South Australia, Australia

***Title**: Civil Engineering Design Project, Civil Engineering Department*

***Reasons for selection:** a number of Civil Engineering capstone projects were identified in the study which are linked to real construction projects. The particular experience selected for this case study at the University of South Australia combines a carefully designed assessment process with a project that sees the entire cohort of 60 students working together as one 'company' on the task. This project has been continually developed and improved over the past 15 years and offers a robust model that is seen to be highly successful.*

Overview of Program

The Civil Engineering degree program at the University of South Australia integrates project-based learning throughout the curriculum. The *Civil Engineering Design Project* is a compulsory capstone module taken in the first semester of the final year of the civil engineering degree. The 14 week module is '*focused around a group learning experience, as the whole class works as a self-managed design consultancy for the duration of the project'*. Mirroring the processes seen in real construction projects, students are asked to develop and present tenders, feasibility studies, concept designs and finally detailed designs for the brief given. Each year, a real project in the early stages of planning or construction is identified, and a partnership established with the relevant industry group. Through this partnership, a suitable project brief is developed and the required permissions are obtained for the students to have access to any relevant site information such as geotechnical reports or environmental assessments. Examples of recent project briefs include the redevelopment of Adelaide Airport or a housing development on a site that had been contaminated by industrial overuse. The three stages of the project are outlined below.

- ***Expression of interest***. During this initial 2-week 'tendering' stage, students are divided into groups of 6-8 and asked to develop a tender for the feasibility study/conceptual design phase, based on the project brief presented. The tender document must contain a number of defined elements, such as a company capability statement, conceptual sketches and a schedule of work. All teams present their tenders to a panel of faculty and industry partners, and one successful tender is selected. The full cohort then form one new 'company' to take forward the specification from the winning tender, and assign the various technical and non-technical working teams within the 'company' structure. Each student is encouraged to take a leadership role at some point in the overall process, and no individual is able to hold a leadership position in more than one phase.
- ***Feasibility study and Conceptual Design***. In this 6-week phase, the new 'company' develops *Quality Management System*, *Feasibility Study* and *Environmental Impact Assessment* reports, based on various environmental, societal, technical or economic factors.
- ***Detailed Design***: during this final 6-week phase, the 'company' must produce *Detailed Drawings and Calculations*, a *Specification* and a *Bill of Quantities*. The final project is presented to a panel of faculty, industry partners, representatives from the university senior management and any interested public.

Students are required to attend eight timetabled hours per week, which are allocated principally for group work but also may be used for guest lectures or industry presentations. It is expected that, on average, students will spend a further eight hours outside class per week on the module.

All students are required to keep a work diary, documenting their progress, issues encountered and reflections on their learning. At the end of each phase, the overall 'company' project manager must also submit a report summarizing the 'company' progress and performance and incorporating feedback from the various team leaders and members on the overall learning outcomes.

Learning outcomes and assessment

The learning outcomes specified for the module are to:

- *consult with a client to establish a brief which aims to achieve broadly-stated final objectives in the field of civil engineering;*
- *apply judgment to situations where the requirements of development and the need to conserve the environment come into conflict;*
- *draw up a set of enabling objectives which if followed will achieve an agreed objective;*
- *identify and obtain, where possible, all data, surveys, reports, standards and codes of practice needed to achieve an agreed objective;*
- *report outcomes of investigations in a professional manner acceptable to a client;*
- *understand the management of project teams and budgets.*

A 'triangulation' process is used in the assessment of the module, focusing in turn on the individual, their workgroup and the full class. Links between the assessment regime and the learning outcomes are made explicit to the students. Around 20% of the assessment is focused on the individual, although other marks are moderated by a process of peer assessment. A more detailed overview of the assessment process is given in the publication referred below.

Operational information

Scale	The full cohort of final year students, currently around 60, take this module. During the initial tendering process, students work in groups of 6-8, but once the final proposal has been selected, the full cohort operate as a single 'company'. It has been observed by the module leader, however, that a cohort of 60 is probably the maximum number that can be sustained in a single 'company' while still providing meaningful tasks for each individual. Larger cohorts may require the student group to be divided into two smaller 'companies'.
Resourcing	Project costs are negligible.
Staff commitment	Two faculty members run the overall project. All faculty within the department are also asked to be on 'stand-by' to offer specialist advice if requested by the students. The industry 'client/s' at the local development engage with the students throughout the project. A small number (2-3) of regular industry speakers give presentations throughout the module, on topics such as 'quality management'.
Transferability	Both the structure and the assessment processes have been well designed for this module, which would provide a robust model for transfer. Issues for adoption include the establishment of partnerships with appropriate industry partners, the identification of a suitable project brief and the management of the large 'group'.
Other issues	A dedicated project room in which the full cohort can meet would be of great benefit.

Further information

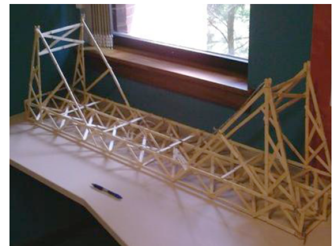
- Mills, J.E., 2007 "Multiple assessment strategies for capstone civil engineering class design project", 18th *Annual conference of Australasian Association for Engineering Education* 10-12 December, Melbourne, Australia.

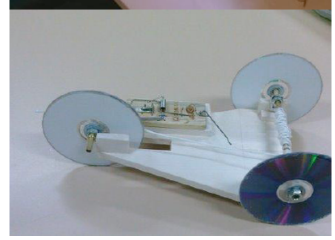
B.3. Australian case study 3: Curtin University of Technology, Australia

***Title**: Engineering Foundations: Principles & Communications*

***Reasons for selection**: the case study has taken a simple introductory design/build exercise and incorporated additional learning outcomes in communications, teamwork and the understanding of professional practice. The exercise encourages 1st year engineers to better understand the various stages of a real engineering project and exposes them to the communications challenges encountered at each stage.*

Overview of Program





Engineering Foundations: Principles & Communications is a mandatory 14 week unit for all 600 first-year engineering students at Curtin University of Technology. The experience seeks to introduce students to both the principles of engineering and also the challenges of working in real engineering environments. As with many first-year introductory projects, students are asked to build simple engineering constructions – in this case either a popsicle bridge or a mousetrap-powered vehicle. However, in this unit, teams must design one product (either the vehicle or the bridge) and then manage the tendering for and construction of the other product, based on a different team's design. The entire project is structured and managed around the typical processes seen in engineering practice and the products are designed and constructed under the basic condition that all vehicles must be capable of traveling over all bridges.

The full cohort is divided into two halves, A and B, and each half is divided into groups of 5. The groups from half A are asked to work on the design of the bridge while the half B groups design the vehicle. On completion of the design phase, each group is given the designs produced by three groups from the alternative half of the cohort and are asked to develop a tender for each product construction. In other words, those groups who designed a bridge will tender to construct a vehicle and vice versa. Groups must then construct one of the designs for which they submitted a tender – where possible, this will be the preferred tender as judged by the designing group. The final project phase involves testing of all products.

Weekly timetabled sessions for the unit include a 1.5 hour briefing session, and 1 hour skills development workshop and a 1.5 hour production meeting. The four overall project phases (design, tendering, construction and testing) are discussed in more detail below.

1. ***Design ph*ase**. Students, working in groups of 5, are provided with a brief to design either a popsicle bridge or a mousetrap-powered vehicle. For their design, each group must develop complete specifications, drawings and a disposal plan, as well as the criteria by which they will evaluate incoming tenders.
2. ***Tendering phase***. The design specifications from each group, prepared in phase 1, are then given to three randomly selected groups who are asked to produce a tender to construct the product. On completion, these tenders are submitted back to the original design group, who must assess and rank the submissions in order of preference.
3. ***Construction phase***. Groups must construct one product for which they produced a tender, based on the drawings and information provided by the 'design' group. During the construction phase, groups are encouraged to keep up an active dialogue with their partnered design group, to minimize the chances of misunderstanding and error. On completion, the product is formally handed over to the original 'design' group to verify the accuracy of construction and predict its capabilities during testing.

4. ***Testing phases***. The day-long testing of the products is conducted in two stages. Firstly, the basic condition that 'all vehicles must be able to travel over all bridges' is tested by randomly allocating bridges to vehicles. The second stage involves individual testing of each product – a speed, distance and accuracy of prediction for the *vehicle* and a load, load to weight ratio and accuracy of prediction for the *bridges*. Prizes are awarded to the most successful groups.

Learning objectives and assessment

All assessment during the unit is both formative and summative. The assessment process takes an equal weighting of marks from each of the four project phases:

- Phase 1: Drawing and design documents and company diary
- Phase 2: Contractors tenders, designer's review, company diary and project progress report
- Phase 3: Handover process, company diary and site visit report
- Phase 4: Performance testing and oral presentation

Operational information

Scale	The total first year engineering cohort of 600 is divided into 2 groups, who take this unit during either the first or second semester (alternating with a parallel *Design* module). Students work in groups of 5.
Resourcing	The set-up and operational costs for this module are relatively low and do not extend beyond the costs of the popsicle sticks, mousetraps and catering for the final presentation. The most significant costs for the unit are the staffing commitments.
Staff commitment	Four core members of faculty staff are assigned to the module, include one module leader, one coordinator (who works half-time on the unit) and 2 faculty members who act as the 'clients' for the production of the vehicles and bridges. Additional support includes 6-7 faculty tutors for the communications element of the unit, and 6-7 PhD students who act as technical coordinators for the student groups.
Transferability	The unit offers a relatively transferable model, with very high student numbers and low resource requirements. In any transfer of such an activity, careful through must be given to how the groups should be managed along each phase of the project.
Other issues	Communications between the various 'designing' and 'constructing' groups is an important part of this exercise, so the provision of appropriate project space would be important. In addition, the processing/management of the group documentation and submissions throughout the 14 week exercise may require dedicated effort.

Further information

- Lindsay, E., Munt, R., Rogers, H., Scott D. and Sullivan, K. 2008. Making Students Engineers, Engineering Education 2008, Loughborough University, England 14 -16 July 2008.