The Royal Academy of Engineering

National HE STEM Programme

Enhancing Engineering Higher Education:

Outputs of the National HE STEM Programme

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Foreword

The National HE STEM Programme (2009–2012) took place against a backdrop of significant change in the higher education systems in England and Wales. Tuition fees, arrangements for student finance and control of student numbers all changed in a move to put the student at the centre of higher education. The changes introduced new drivers on teaching quality, employment outcomes and widening access.

Throughout the changes, the status of engineering as a strategically important subject remained unchanged in both England and Wales as did the social and economic imperatives of producing enough high calibre engineering graduates to tackle the grand challenges of sustainable economic growth, climate change, energy security, fair water distribution, food production and better health outcomes for all.

In managing the engineering strand of the National HE STEM Programme, the Royal Academy of Engineering wished to provide as much flexibility to Higher Education Institutions and to engineering academics as it could; hence the tactic of providing funding for a wide range of themed projects through competitive bidding. Every engineering department has to react to the constants and changes in engineering Higher Education according to local context. No two departments are alike; each one positions itself in a new market for students in a unique way according to its strengths and constraints.

It has been fascinating to watch colleagues in engineering departments respond to their varying needs with project proposals that tackle a range of issues. A representative sample are summarised in the pages that follow.

What did these projects achieve for engineering Higher Education? It is too early to tell of course but the programme as a whole has highlighted a number of things. Engineering academics are acutely aware of the drivers on the system and generally proposed projects to tackle issues on which they are being measured; student recruitment, progression, retention and employability being notable examples. There is genuine interest in pedagogy but scholarship in engineering education still appears to be relatively rare. Finally, the role of employers in engineering Higher Education is widely recognised and valued, but more could be done to use their potential as contributors to teaching, learning and assessment.

The engineering component of the National HE STEM Programme has been shaped by the changes to the environment in which it unfolded. The support the programme was able to give to engineering looks to have been timely indeed.

Professor Matthew Harrison
Director, Education

The Royal Academy of Engineering
June 2012

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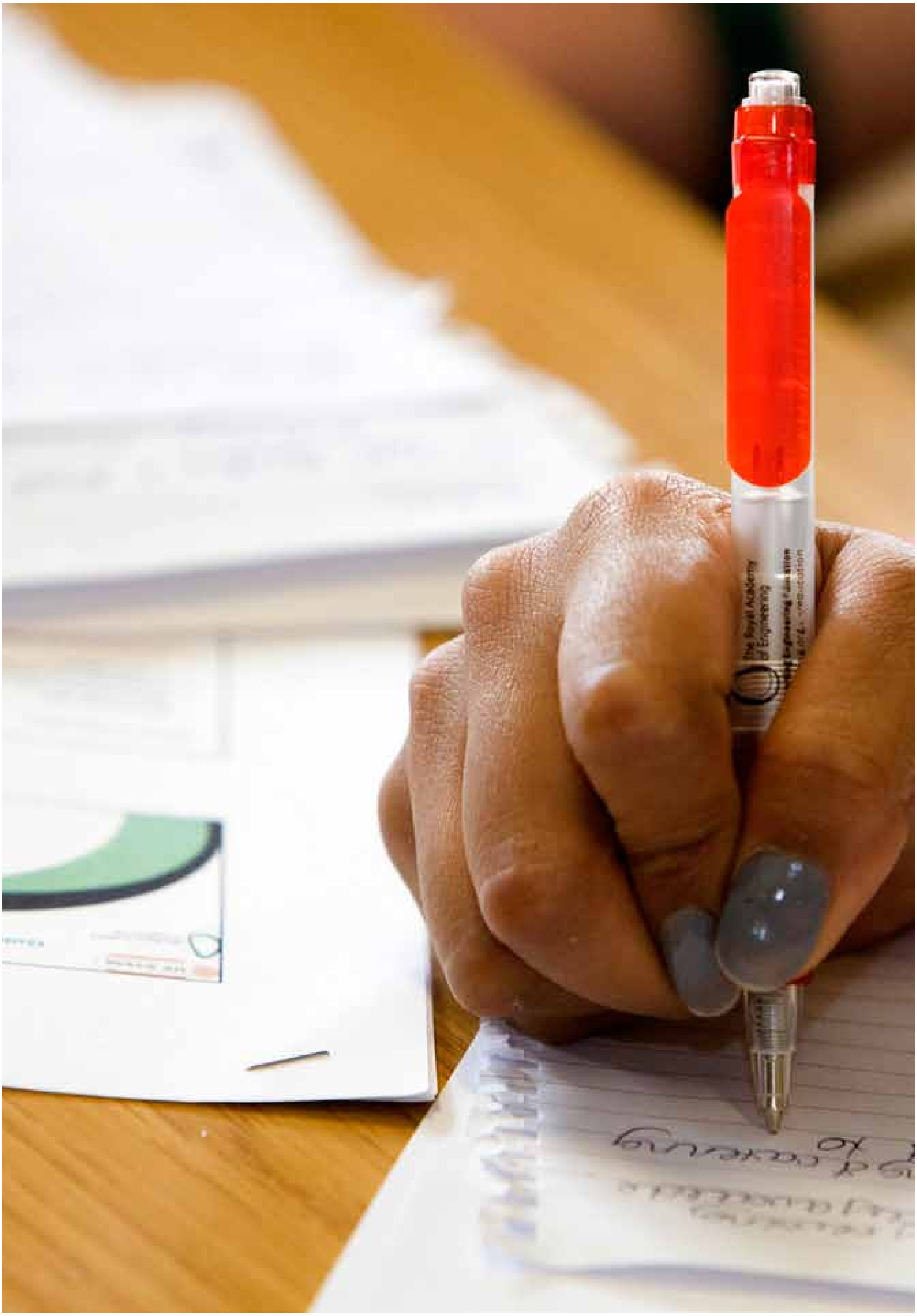


Introduction

Delivery of the National HE STEM Programme – Engineering Strand

Hal Igarashi and Sapna Somani

The Royal Academy of Engineering (the Academy) was one of four professional body partners working with six university partners in the National HE STEM Programme from July 2009 to July 2012. The National HE STEM Programme was a £21 million programme of activity directed at supporting higher education institutions (HEIs) throughout England and Wales to encourage the exploration of new approaches to recruiting students and delivering programmes of study within the science, technology, engineering and mathematics (STEM)[1] disciplines, particularly the strategically important but vulnerable subjects of engineering, mathematics, physics and chemistry. The Programme was funded by the Higher Education Funding Council for England (HEFCE) and the Higher Education Funding Council for Wales (HEFCW).

1 Within the context of the National HE STEM Programme, STEM refers primarily to the disciplines of chemistry, engineering, mathematics and physics.

The National HE STEM Programme (the Programme) enabled the transfer of best practice in curriculum innovation and widening participation and diversity across the higher education STEM sector, facilitating its wider adoption and encouraging innovation. Through collaboration and shared working, the Programme focused on sustainable activities in order to achieve long-term impact within the higher education sector.

The Academy led the disciplinary strand for engineering and, through three funding calls (in March and September of 2010 and February 2011), awarded a total of £475,000[2] to 60 one-year projects. Bids for funding were invited for innovative proposals in curriculum innovation, engineering for society (including widening participation and diversity) and education research. The importance of engaging employers to support these activities was a central premise in accordance with good practice set out in the Academy report *Engineering graduates for industry* and, during the course of their project activities, project leaders were encouraged to engage with employers and collaborate with other universities in order to pool expertise.

Funds were allocated against stringent criteria and successful bids demonstrated the intention to deliver specific outcomes within the funding themes and showed that any innovative knowledge or practice developed could be sustainable or transferred to/adapted by other HEIs to inform and improve pedagogic practice. Project funds were not intended to provide full economic recovery of costs, but to enable innovative work to be carried out. University departments that were granted funding were required to provide evidence that funding would be matched or that other "in kind" support would be made available in order to complete the project.

Small-scale projects are usually undertaken by enthusiastic academics with the intention of developing ideas that can be embedded into departmental curricula. The Programme engineering team at the Academy were assiduous in advertising the calls throughout England and Wales and events were held in each of the regions to encourage engineering departments to make expressions of interest. In the first call, 17 proposals were received and 11 were funded. In the second call, 84 expressions of interest were received, 39 were invited to submit full proposals and 35 were funded. In the third call, 53 expressions of interest were received, 22 were invited to submit full proposals and 14 were funded.

11 projects for engineering in society (widening participation and diversity) were funded across the programme, nine of which involved the support of employers. Widening participation projects were distinct from outreach in that they were focused specifically on curriculum development or research that enabled access to higher education for diverse groups (whereas outreach is targeted at school pupils). Total funds distributed to this theme were £103,000. Three projects were funded in the North West region (totalling £26,000), one in the North East for £6,000; two in the Midlands and East Anglia (totalling £16,000) and five in the South East (totalling £55,000).

15 projects, which examined various hypotheses on curriculum innovation or pedagogic practice, were commissioned for engineering education research. The total funds allocated to this theme were £110,000. Seven projects were funded in the Midlands and East Anglia (totalling £50,000), two in the South East (totalling £14,000), five in the North East (totalling £40,000) and one in the North West for £6,000.

There were 34 projects funded under the theme of curriculum innovation. The total funding allocated was £261,000 and 22 of these projects involved engagement with employers. There were 12 projects in the Midlands and East Anglia (totalling £75,000), ten in the North East

2 Figures have been rounded to the nearest £1000.

(totalling £83,000), eight in the South East and London (totalling £67,000), three in the South West (totalling £27,000) and one in the North West for £9,000. Of these projects, five were for the purpose of workforce development (representing 8% of all small scale projects funded). Two of these were in the North East, one in the North West, two in the South East.

Additionally, five strategic outreach projects with the aim of attracting young people into STEM careers were established and funded in April 2010. A total fund of £200,000 was committed and the funds were distributed to the University of Wolverhampton for the Midlands and East Anglia (£41,000), the University of Liverpool for the North West (£36,000), the University of Bradford for the North East (£36,000), the University of Southampton for the South East (£41,000) and Swansea University for Wales (£46,000).

The Academy also secured a further £773,000 to fund a number of larger strategic projects that it would oversee. These included the *Nuclear Island* project (£105,000), the *Engineering Gateways Workforce Development* project (£101,000), the *Support for University Technical Colleges* project (£64,000) and two large-scale *Practice Transfer Adopters* projects (£83,000). In STEM subject disciplines, there were three large-scale projects in mathematics, three in engineering, two in chemistry, one in physics and one cross-STEM. These were funded at approximately £30,000 each. Two very large-scale collaborative projects were funded at £60,000 each.

The Academy established robust mechanisms for project monitoring and progress reporting and provided a programme of support for project leaders. This was largely successful in bringing 63 out of 65 projects to successful completion. Face-to-face meetings were set up in the early stages of each project to develop a rapport, explore the objectives and proposed delivery of the project in detail and offer advice and support. It was also possible to ascertain which projects would need closer support. Further communication with project leaders was primarily by email, with some contact by telephone. Email was also used for regular communication to remind project leaders of milestones, transmit documents and templates and control invoicing and reporting. This was generally well-received. At the request of project leaders, the Academy also hosted events to support strategic projects which had particular need of a high profile venue and image, and project leaders involved Academy advisors in their own project workshops, colloquia and dissemination events and sought their assistance with evaluation. Throughout the programme, the Academy hosted four seminars for the purposes of support, dissemination and evaluation and two seminars for employer engagement. Three of these were held by the Academy and three were hosted by Loughborough University, Coventry University and the University of Bradford.

Project leaders were required to write a case study of their work and complete an evaluation survey at the end of their project. The case study set out the background literature, the rationale for the project, the method and the outcomes and conclusions. Prior to publication, each case study was subject to a two-stage review, firstly by the advisor who was familiar with the project and then by someone with no prior knowledge or expectations (thus providing a third party review). Finally, the case studies were proof read for points of consistency, order and any residual typographical, grammatical or syntactical errors. Project leaders requested additional support in the writing of case studies and a template and guidelines were produced for that purpose. This enabled project leaders to provide case studies of a consistent format and standard which, in the majority of cases, reduced the need for more extensive reviewing and proof reading.

The case studies are published under Creative Commons licences and are stored on the London Engineering Project's National HE STEM Programme webpage and on the main National HE STEM Programme website. They are listed in Appendix to this book. The collected works contribute to a legacy of knowledge on effective and innovative practice in engineering education and provide an accessible audit of the entire body of work funded by the Academy.

154 expressions of interest were received, of which 60 were funded and 58 published in full. Synopses of 26 projects are provided within this publication: 17 in curriculum innovation, six in education research and three in widening participation and diversity. Eight are taken from projects in the South East region, seven from the Midlands and East Anglia region, nine from the North East region and two from the North West region.

In selecting the case studies for publication in this book, a representative spread of exemplary synopses was sought, demonstrating innovative, transferable and potentially transformative and sustainable practice which would contribute to engineering pedagogic knowledge. The proof reading of case studies and copy editing of the synopses was carried out by the Centre for Engineering and Design Education at Loughborough University.

Overview

Qualitative meta-analysis of the response from higher education

Hal Igarashi

This overview presents a meta-analysis of the engineering strand programme delivery and is an account of observations of the issues that academics appear to be exercised by when they bid for funds and engage with the themes.

Each call took approximately ten weeks from launch to allocation of funds. The greater proportion of time was allocated to enable proposers to fully develop their ideas and write appropriately extensive bids for funding. However, more than 80% of proposals were received during the last 24 hours of the call, a significant proportion of which were received within hours of the deadline. Most proposers were committed to finding universities and employers with whom to collaborate. These designated partners did not necessarily readily commit, but instead took time to thoroughly consider and/or gain the approval of departmental managers. Additionally, university finance departments were slow to process invoices and, in some cases, service level agreements had to be specifically redrawn to suit the particular requirements of the university's legal department.

After the first call which produced a modest response, funding was increased from around £5,000 per project to £10,000. For the second and third calls a two stage bid process was also introduced. This streamlined the process by providing an initial selection of potentially viable projects and reduced the incidence of bid writers making lengthy applications which may have had some risk of rejection. Brief expressions of interest were invited and if the proposed project was considered to have the potential to contribute to the aims of the Programme then proposers were invited to expand the expression of interest into a full proposal. By increasing the funding level per project, a larger number of applications for potentially more ambitious proposals were received. Although the total number of projects that could be provided for with the available funding was less, this was offset by the reduced administrative demand and a higher percentage of funds were made available for actually delivering the projects.

Proposers bidding for funds inevitably interpreted the criteria in diverse ways and a large number of speculative expressions of interest were received which had broader aims than the allocated funding themes, including equipment purchases, continuation funding for work in progress, work considered to be normal departmental business and work in subject disciplines which were out of scope. This dissonance in expectation led to approximately 60% of all expressions of interest being rejected at the first stage. By way of illustration, proposers frequently presented bids to the engineering in society fund for small projects which were in fact proposals purely for outreach activity. Whilst outreach may have widening participation attributes, equally it may not, and the engineering and society and outreach funds were distinct and separate. Whether these issues were confused is not fully understood, but many university-led outreach activities tend to be marketing activities designed to increase the attractiveness of a particular subject. For the purposes of the engineering strand programme, widening participation and diversity were defined as accessibility and inclusivity of courses. Only bids for accessibility were received. Although a proportion of engineering undergraduates are international students, there were no proposals for developing inclusive curricula.

It can also be seen that expressions of interest for proposed activities in each funding theme also had quite specific underlying aims relating to improving student attendance, retention and completion rates, aspects of student learning support or learning enhancement and student transition from school to higher education. These aims are generally consistent with academics' concerns regarding improvement to pedagogic practice and learning and also align with the performance criteria of academic posts.

There continue to be concerns about the capacity of employers to provide work placements and the ability of universities to develop appropriately productive relationships with them. Many projects clearly valued the input of employers into curriculum enhancement and delivery, although focus on the benefits of work-based learning or involvement of employers in developing (and especially assessing) undergraduate modules was rare and considered impractical by some academics.

University departments provided varying degrees of "in kind" support in order to complete their projects, either through direct financial contribution or staff time to which a quantum could be applied. A significant number of projects (62%) engaged employer partners who gave staff time and expertise, donations of equipment or materials and/or direct financial support. Applicants were required to declare that they had not received funding from other public funding sources.

Project plans were required to demonstrate measures to disseminate and embed developments in departmental practice. However, sustainability depends on a number of factors, many of which are independent of a project's immediate outcomes (for example, if an academic takes up another post then the development might go with them). Embedding good practice and sustainability therefore depends on collaboration within university departments and tangible impact has to be seen in the longer term. Many project leaders depended largely on the Academy for dissemination.

It is clear from the number of expressions of interest that there is widespread concern in academia about the difficulties students have with acquiring the specific conceptual knowledge that enables learning. Much of this is mathematical and reflects ongoing issues about the mathematical ability of undergraduate engineering students. Others relate to concepts in materials, structural analysis and kinematics, control engineering and electronics. There were a number of projects for student learning support which made innovative use of information and communication technology platforms to provide simulated environments or models.

Other areas of concern relate to the preparation of students for employment. A small number of projects sought to understand the factors that affect employability or wanted to develop innovative curricula that would encourage the acquisition of employability skills such as team working, communication, project management, open-ended problem solving and self-development. In August 2010, Oakleigh Consulting, in partnership with the University of Staffordshire, published its report (*Understanding the information needs of users of public information about higher education*) to the Funding Council for England. Given the impact of this report, and the subsequent requirement placed on universities to provide information on employment rates for graduates, it is surprising that there were not more projects addressing this issue.

Many of the education research projects are better described as specific investigations into particular aspects of practice. There were only three projects in which the project teams attempted to really research the fundamental pedagogy of engineering education and to try to understand how engineering students learn, what they find difficult and how learning can be better enabled for them.

A number of projects did not run according to plan and project timelines had to be extended. In other cases, collaborating partners dropped out or key engagements with employers, schools or other universities were only partially successful and planned project outcomes had to be renegotiated. In extreme cases a small number of projects took twice as long as planned however, a similar number completed ahead of schedule. The majority of project leaders reported that their project had yielded unexpected goal-free benefits.

The majority of expressions of interest were received from regions in which there are higher densities of universities with engineering departments. None were received from the Anglia region and very small numbers from the South West and Wales. Project leaders reported a variety of ways in which they thought it would have been easier for them to find out about the available funding however, many of these had actually been employed by the Academy in advertising the funding calls. It is possible that emails sent to designated persons were not acted upon or passed to individuals with appropriate interest or remit in engineering pedagogy. Funds for small-scale projects were modest and this may have deterred some academics from submitting expressions of interest. In the second and third calls funding allocated to projects was increased to encourage more academics to apply. More expressions of interest were received for the second and third calls and this may have been due in part to increased awareness of the availability of funds. A large fund for outreach in the South West region had to be re-allocated due to there being no take-up and lead universities in two other regions had to re-profile planned outreach activities to use all the funds allocated to them.

Amongst projects that focused on engagement with employers, there seemed to be little interest in workforce development and work-based programmes and only 8% were specifically about workforce development. In contrast to HEFCE expectations that workforce up-skilling initiatives should target transition from level 3 to level 4, there was no interest from employers in such programmes. At an event hosted by the Academy for the purpose of engaging employers in the National HE STEM Programme none said that they could see a rationale for up-skilling sections of the workforce from level 3 to level 4. All employers however said they would support progression for selected individuals who demonstrate ability and motivation. The workforce development projects funded by the Academy were all curriculum innovations focussed on undergraduate training or postgraduate continuing professional development.

Only a few collaborative projects appear to have attempted to engage new partners or networks. Both universities and employers continue to collaborate with established partners and networks and appear reluctant to explore other possibilities or develop new collaborations. In the few instances where this did happen, the collaborations were particularly successful, but inevitably required considerable investment in time and the resources of a dedicated individual. In some cases the expertise of external agents was contracted in for this purpose and to assist in the delivery of particular aspects of the project.


Pure Liquid ink

Evaluation Summary

An evaluation of The Royal Academy of Engineering's contribution to the National HE STEM Programme

Ivan Moore and Sapna Somani

Introduction

The previous chapters outline the nature and extent of the programme managed by The Royal Academy of Engineering (the Academy). Project funding and support was offered under three themes and in three phases. Each phase was initiated with a call for bids to the fund and projects in each call were of one-year duration. As each project drew to a close, project leaders were invited to return an evaluation survey questionnaire which requested both quantitative and qualitative responses. The survey was comprehensive and a full record of the returns is provided on the National HE STEM Programme (the Programme) website at **www.hestem.ac.uk/royal-academy-engineering**. This chapter provides a summary of the most significant, useful and unusual responses, along with a commentary on each section of the survey.

The survey involved 53 questions which were organised under eight headings:

1. General organisation, administration and support
2. Outcomes and objectives
3. Impact
4. Employer engagement
5. Dissemination
6. Sustainability
7. Engineering for society
8. Education research

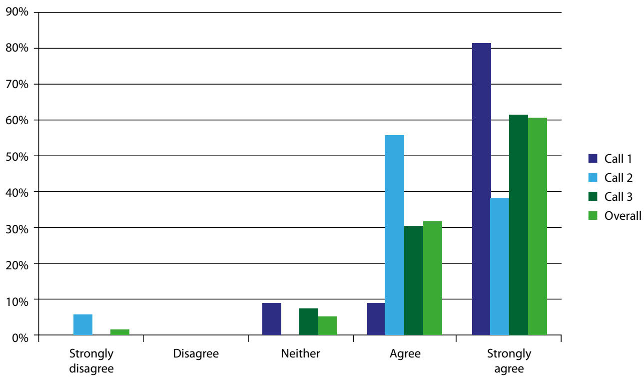
The last two sections were for those projects involved specifically in these themes. Of the 60 projects, returns were received from 58. Not all sections of the survey were relevant to all respondents. Five-point Likert scales were used for questions requiring a quantitative response.

General organisation, administration and support

Q1. The bidding process was fair

92% of respondents agreed or strongly agreed with this statement (Figure 1). Of the two who strongly disagreed, one respondent provided consistently positive comments in support of the programme, so it is possible that this respondent misinterpreted the question.

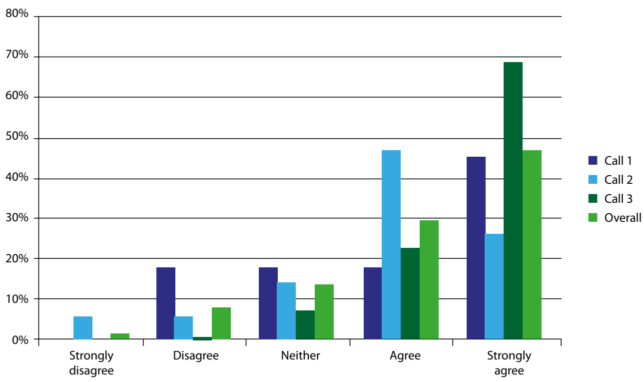
Figure 1. Bidding process was fair



Q2. The bidding process was easy

76% agreed or strongly agreed and 10% disagreed or strongly disagreed with this statement (Figure 2). It is interesting to note that Call 1 received the least positive response, although it was a simple, one-stage process. Call 3 seemed to attract the most positive overall response, although the bidding processes for Call 2 and Call 3 were identical.

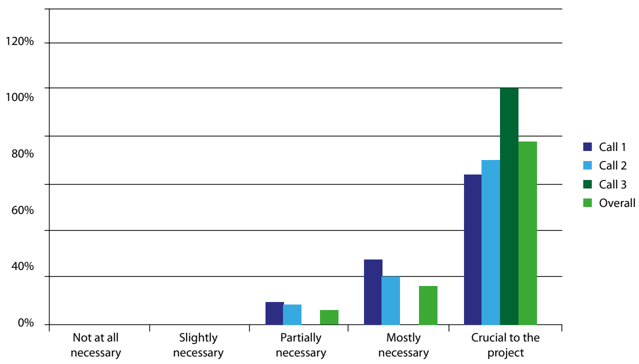
Figure 2. Bidding process was easy



Q3. To what extent did the funding enable you to pursue your project?

All respondents indicated that the funding was necessary, with 78% indicating that it was crucial to the project (Figure 3). This shows that, although the amount of funding was relatively small (up to approximately £5,000 per project for Call 1 and £10,000 per project for Calls 2 and 3), it was hugely important in enabling the projects. The Academy team decided that it wanted to attract bids from teams who were not simply seeking funding, but had a pre-existing requirement or whose plans showed alignment with the Programme's objectives.

Figure 3. To what extent did the funding enable you to pursue your projects?



Q4. How did you find out about the calls for funding?

Responses indicated a wide range of sources of information. These included attendance at the Programme's seminars and events, email notifications to distribution lists, information from colleagues, the Higher Education Academy Engineering Subject Centre website and email circulars and involvement in other related networks. Although email distribution lists included heads of engineering, it is unclear whether they passed on the information to their staff as requested, as none of the respondents indicated their head of engineering as a source of information. It is clear, however, that many staff were actively seeking funding opportunities and were effective at scanning for them. Nonetheless, responses also indicate that raising awareness of funding opportunities requires funding bodies to employ a wide range of methods.

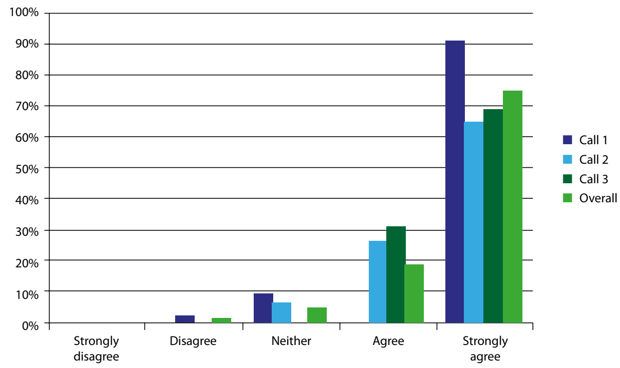
Q5. What other ways of informing you of the Programme would have been effective?

Most respondents indicated that the methods used were comprehensive. A significant number of respondents suggested direct contact with the institution, school or subject head. Given that this was done, and given the response to Q4, it would appear that school-based contacts such as heads of engineering are not effective conduits for passing funding information to staff.

Q6. How helpful was the support provided by The Royal Academy of Engineering?

94% of respondents indicated that the support was either mostly helpful or very helpful (Figure 4). Only one respondent indicated that it was not very helpful, but this respondent went on to explain that this was because they didn't need any help.

Figure 4. How helpful was the support provided by The Royal Academy of Engineering?



Q7. What other support would you have welcomed?

Most responses indicted that project leaders were more than satisfied with the support provided and there were few suggestions for improvement. These were mostly to ask for more frequent meetings and better internal support from their home institution. There was overwhelmingly positive feedback on the support provided:

- *'The level of support was far greater than I have received for any other project, irrespective of financial value.'*
- *'I was satisfied with the support we received. I appreciated the independence and trust placed upon us and the fact that our advisor and the other Programme staff were always quick to reply with a helpful response whenever we asked. I was particularly glad that our advisor both attended our workshop and also tailored the case study guidance for research projects.'*
- *'The support that was provided proved to be useful. Having a contact was crucial. I don't know how it could have been improved.'*
- *'Possibly more frequent discussions on progress and networking/collaboration opportunities by telephone or Skype.'*

Q8. Was there any aspect of support that you did not want or need?

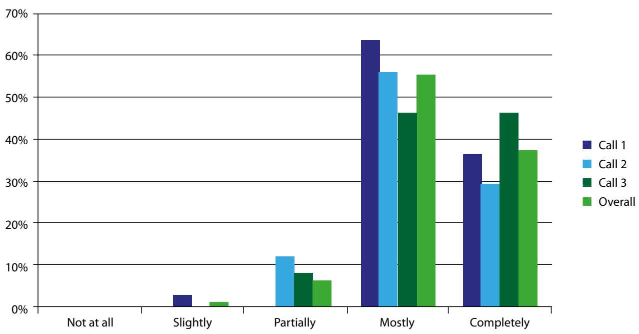
The most significant response was a request for more streamlined, focused email contact.

Individual project outcomes and objectives

Q9. My project met its aims and objectives

All respondents felt that their project had met its objectives to some extent, with 55% indicating that they were mostly met and 37% indicating that they were fully met (Figure 5). This is considered to be a good outcome, especially since some project leaders indicated through other means that they had achieved unanticipated outcomes or learning.

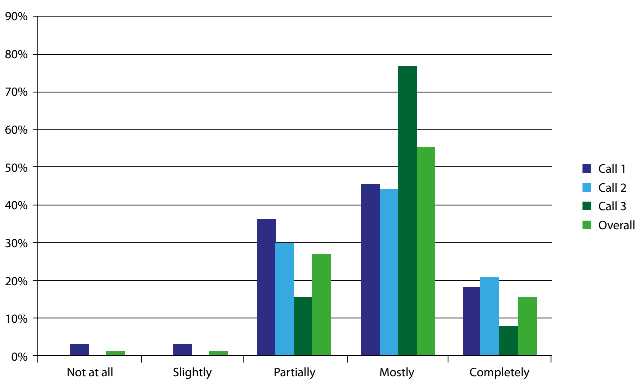
Figure 5. Individual projects met their aims and objectives



Q10. The project ran according to plan

Responses showed a close to normal distribution, slightly skewed to the positive end (Figure 6). Given the complexity of some projects and the risks identified at the bidding stage, this distribution would appear to be reasonable. The fact that most projects achieved their objectives indicates that risk analysis and exception planning are vital to the success of a project. It is also felt that the flexibility offered by the Academy contributed to successful outcomes, despite projects not running to plan.

Figure 6. Individual projects ran according to plan



Q11. Describe any unexpected benefits achieved

Many responses indicated that projects received broader interest and engagement with students, staff and employers than anticipated, that students were more excited by the developments and that staff attitudes to teaching had changed for the better:

- *'There has been a greater amount of interest shown across the faculty than I was expecting and a number of people came forward who have interest in this area.'*
- *'Great interest and commitment from industry key stakeholders.'*
- *'The outlook of two members of academic staff towards teaching has changed for the better.'*
- *'Meeting other people, particularly from a range of diverse backgrounds, networking, exchanging ideas, seeing the work of others* [and] *explaining this project to other people meant that we had to be very clear in our own minds what we were trying to achieve and what approaches were possible and appropriate.'*
- *'Quite significant community-building in education research within the department.'*
- *'Students were more excited than expected about the developed resources.'*

Q12–14. Unanticipated difficulties and how they were overcome

These mostly referred to human resources in terms of gaining student engagement, staff involvement and time to work on difficult aspects of the projects. A common response was that it often took longer than anticipated to carry out many of the activities and, indeed, to even get the project started. However, the Academy's flexible approach to project timescales helped to overcome these difficulties.

Impact

Q15–20. Involvement of people, departments and institutions

Many projects involved departments outside the host department. The involvement ranged from attendance at seminars to active engagement with the project.

Many projects *referred* to involvement of other institutions. Again, this ranged from attendance at seminars to active engagement and included targeting other institutions for dissemination activity.

Many projects referred to the active involvement of staff *within* the institution. Numbers ranged from two to 40, with the most common being between three and five other staff. Some respondents also referred to employer involvement.

In most cases, one or two institutions were actively involved in the project, although in some instances much larger numbers were involved.

Direct student involvement in projects ranged from no students (in some cases) to over 400. Several projects returned estimates of between 200 and 400, with many more returning numbers between ten and 50.

These figures increased significantly for student numbers anticipated in the future.

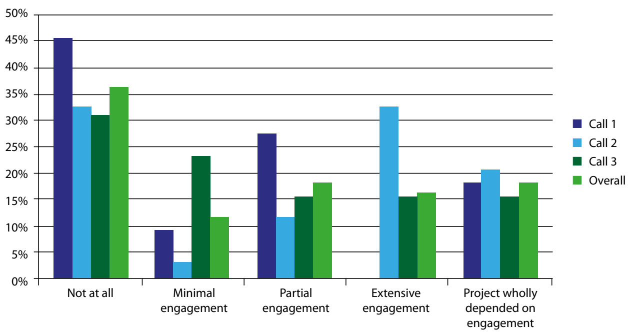
Overall, the impact of projects seems to go beyond the small number of staff and students in the host department and spans subjects, institutions and employers. As with many development projects, impact is anticipated to be greater *after* completion.

Employer engagement

Q21. To what extent did your project set out to engage employers?

52% of projects indicated that they had sought some form of engagement with employers, with 16% seeking extensive engagement and 18% seeking total engagement (Figure 7). This compares well with the programme target of 33%. It is worth noting that only 9% of those that sought engagement were wholly dependent on it.

Figure 7. To what extent did your project set out to engage employers?



Q22–24. Purposes of engagement

For those projects that did seek employer engagement, a wide range of types of engagement was identified. The most common forms were support with delivery, specialist knowledge input and curriculum enhancement, although research and information gathering were also featured. The most common sectors identified were general engineering, mechanical engineering and civil engineering, with the lowest responses for biomedical engineering and marine engineering.

Q25–27. Reaching and engaging employers

Of the 35 respondents, 79% were mostly or extremely effective in *reaching* employers (9% were slightly or not at all effective) and 76% were mostly or extremely effective in *engaging* employers. It is difficult to interpret these two responses, as the second response (engagement) is influenced by the first (reach). However, a project may have set out to engage, for example, ten employers, but in practice only reached two, showing a poor response to the question of reach, but without reference to the *level* of its engagement (which may have been very high). More data therefore need to be gathered in order to interpret these results more accurately, but we provide them here for the reader's interest.

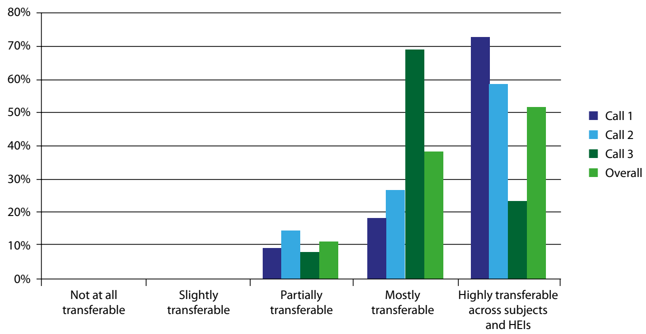
In order to improve reach and engagement, respondents felt that pre-engagement and early interaction with employers would be beneficial. This seems to bear out the view that building on prior networks with employers is important when seeking their engagement in projects.

Dissemination

Q28. Transferability

All projects responded that they believed their project outcomes to be transferable across the sector to some extent. 90% reported them to be mostly or highly transferable (Figure 8).

Figure 8. Outcomes of individual projects were transferable across the engineering sector



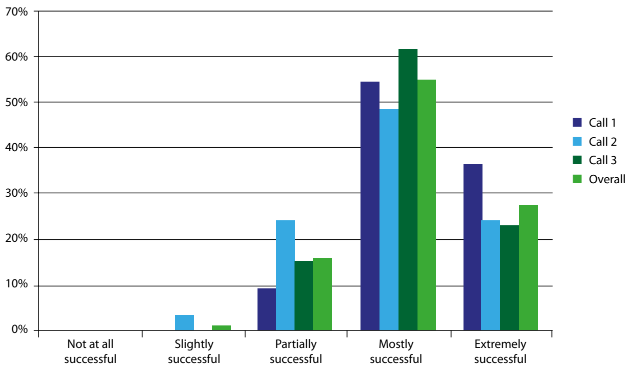
Q29–31. Targets for dissemination

Project outcomes were disseminated within home departments by 70% of projects, within host institutions by 83%, to other institutions by 61% and to employers by 37%. A number of dissemination methods were used, including in-house seminars (60%), Royal Academy of Engineering seminars (58%), regional HE STEM seminars (41%), websites (40%), staff continuing professional development (CPD) (18%) and publication (62%). It would seem that most projects relied heavily on the website dissemination and publication opportunities provided by the Academy and the National HE STEM Programme.

Q32–34. Effectiveness of dissemination activities

83% of projects reported that their dissemination activities were mostly or extremely successful, with 72% saying that they would not change their methods (Figure 9). Of those who would change their methods, few indicated practical transferable practices and most referred to modifications to the Programme of activities.

Figure 9. Dissemination activities were successful



Sustainability

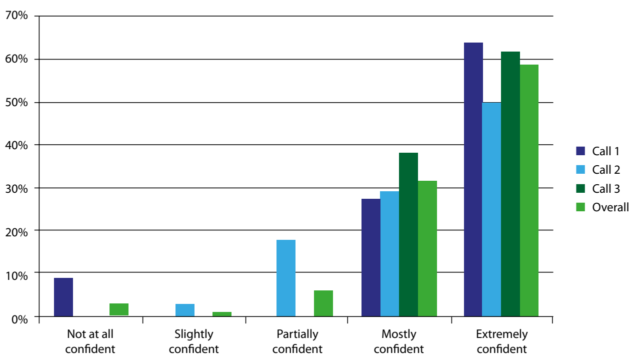
Q35. Outcomes leading to change

The majority of anticipated changes were to curricula (61%) or pedagogy/delivery (69%), with significant changes also anticipated in employer engagement (44%).

Q36–40. Sustaining change

A large number of factors and methods of change were reported and are given in the full evaluation return on the website, along with drivers that need to be put in place to ensure sustainability. There was a high level of confidence in the sustainability of change, with 90% of respondents being mostly or extremely confident (Figure 10).

Figure 10. How confident are you that the changes will be sustained beyond the funding period?

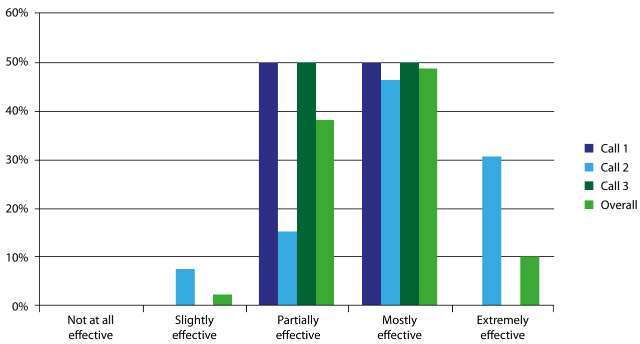


Engineering for society

Q41–45. Reaching and engaging target groups

18% of projects (11) fell into this category, which included widening participation, outreach and inclusion. Widening participation targets focused on Black and Minority Ethnic groups, adults, females and first generation HE entrants. 92% of respondents were highly effective in *reaching* their target audiences; however, they were less effective in *engaging* these groups, with 59% being only partially effective (Figure 11). No projects sought to develop an inclusive curriculum.

Figure 11. How effective was your project in engaging the target groups in the intervention?



Education research

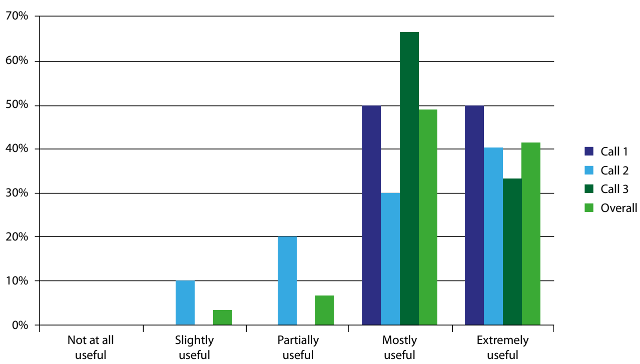
Q46–48. Effectiveness of research

25% of projects (15) fell into this category. 90% of respondents felt they were mostly or extremely effective in engaging with the subject of their research, with 94% reporting that their methodology was mostly or extremely effective (the remaining 6% reported that it was partially effective). Most researchers were able to identify small ways of improving their research methodology without completely redesigning it. A common response concerned timing of interviews, focus groups and questionnaires. In many cases, it was felt that more thought could have been given to aligning the research timescales to better fit the academic year, hence making it easier to engage target subjects (staff and students) in the research.

Q49–50. Outcomes of research

90% of research teams felt that their research was mostly or extremely useful in informing pedagogic practice across the engineering sector (Figure 12).

Figure 12. How useful are the outcomes of your research in informing pedagogic practice across the engineering sector?



Q51–53. Publication and further research

Some 26 publications have already been produced. These have included journal papers, conference presentations and web publications. Nine respondents reported no publication so far, with five of these indicating the intention to publish or that publication was under way. Several researchers have reported multiple publications, with one indicating seven from one research project. It may be seen as disappointing that only 50% of projects actually published their findings, even though 90% felt that their work was important in terms of informing engineering pedagogy. This shows how important it was for the Academy to provide a web-based publication output for all projects in the Programme. It remains to be seen whether this important research will lead to changes in pedagogic practice.

Practically all respondents were able to identify areas for further research. Disappointingly, none of the research project respondents indicated that they had secured any further funding from other sources to continue their research, although several indicated possible sources of further *implementation* funding. This may not be a matter for concern, given that the responses were returned before the projects were completed; however, in the light of responses to Q4 (that staff are actively seeking funding opportunities and are effective at scanning for them), this leads to some concern that funding opportunities for pedagogic research (particularly in engineering) are drying up. This is particularly worrying, as responses to Q3 indicate that only relatively small amounts of funding (up to £10,000) can be very effective in supporting projects, representing excellent value for money, especially in the field of educational research.

Issues

Issues in the management of development projects in Higher Education

Ivan Moore

Introduction

We set out here a discussion of the key issues that need to be addressed for successful implementation of a programme of funded development projects in institutions of higher education. This is based on reflections on the HE STEM Programme and an analysis of the evaluation exercise previously reported within this publication. Whereas, these guidelines are derived from a centrally managed fund which was made available to HEIs across the sector, many of them can be adapted for development programmes that are derived wholly within a single institution.

1 Preparing for the development programme – the call for bids

Preparing a call for bids involves a number of preparatory considerations:

The purpose of the development activities to be supported

Funders need to be clear about the objectives of the overall programme. It is not sufficient to simply say it is an enhancement activity. It helps if it meets a clear set of objectives. These may be, as in this instance, the objectives of the National HE STEM programme, or they may be the objectives in a faculty or institutional strategy. Further, if the objectives are broad, then it will help to organize the programme into a number of funding streams. For example:

1. HE Innovation Projects including Employer Engagement
2. Engineering for Society: Diversity and inclusion in engineering education
3. Education Research

Within an HEI, streams may include employability, retention, skills for professional practice.

The specific objectives and criteria for the call for projects

It will help bidders if they are clear about the objectives funders want them to achieve. Again, it is important to be clear and specific. For example, the Royal Academy of Engineering (the Academy) objectives were that projects would contribute to the development of a national Higher Education STEM sector which:

- Engages collaboratively to increase and widen participation,
- Promotes, supports and champions the STEM disciplines, and
- Is increasingly responsive to the skills needs of both employers and employees

To this end, the overarching criteria for selection of proposals are that projects will:

1. Support increasing and widening participation
2. Enhance the quality of engineering education and its graduate outcomes
3. Develop in students those skills needed by employers

A template for bids – with word count

This will make it easier for potential project teams to explain their proposal. It also ensures that all aspects of the project are addressed by all bids. The Academy template included the following headings:

1. Summary
2. Background/rationale
3. Project action plan
4. BenefitsSustainability
5. Dissemination
6. Evaluation
7. Project plan
8. Risk assessment
9. Funding requested
10. Contribution made by host institution
11. Supporting statement from relevant line manager

Clear submission deadlines and processes for judging bids

If you anticipate a large volume of bids, it may be useful to hold a two-stage process with the first stage requiring a brief expression of interest that summarises each bidder's proposal. The funders can then produce a short list of those invited to submit a stage two proposal.

2 Supporting successful projects

By ensuring they are well designed from the start

The best means of supporting bids is to ensure that they have thought of everything and made it clear in their proposal what they intend to do, how they will do it, how they will address any risks and exceptions, how they will ensure continuing involvement of key participants and how they intend to disseminate their outcomes.

By giving them the opportunity to discuss their plans at key points throughout the project

This involves the funding team in offering to discuss projects at several stages throughout the project. An initial face-to-face discussion at a very early stage will often uncover gaps in the project plan, unanticipated difficulties or other relative weaknesses. It also acts as a sounding board for the project leader to discuss their plans in a way that is often missing in a written project proposal. An early meeting can get the project off to an early start: follow-up meetings can be face-to-face, by telephone or by email according to judgments made on progress and support needed. In most cases, we found that email or telephone follow-up was sufficient and this allowed the team to provide intensive face-to-face follow-up support to the small number of projects that needed it.

By developing a community of practice

This is easier to do within a single institution, as project teams can get together more readily. However, even the organisation of an interim seminar allows project teams to get together to share their progress, ideas and problems within a community of practice. Not all projects will benefit to the same extent, but even the milestone of delivering a short presentation or poster will focus teams on their project. In some cases, contacts made at a seminar have led to useful collaborations within and across projects. Again, these may be easier to establish within a single institution.

By establishing milestones attached to phased funding

Don't give all the funding out at the beginning, leave the teams to get on with it and expect a completed project and report at the end. There are many pressures on staff that can distract them and it is helpful to establish milestones. For example, provide, say a third of the funding at the beginning of the project, another third half way through, on receipt of a written project report and seminar presentation and the final third on receipt of the final report. There may be instances where tension can arise if interim funding is not forthcoming as a report has not been provided, but this tension can be a positive incitement to keep up to speed with the milestones set in the project. Failure to provide an interim report can act as a signal that further support may be needed by the project team.

3 Completing the project and providing meaningful output

Programme managing teams often find this the most difficult and stressful stage of the programme, so it is important to consider the means by which projects can be brought to a successful conclusion. Often, project teams will encounter delays or obstacles, or they discover other developments that their project can lead to and attempt to build these into the project (project drift). In higher education, many projects need to operate within a semester-based academic year, so a delay of even a week or two can lead to a delay of up to a full year. The programme managing team may need to renegotiate the project outcomes to ensure that meaningful outcomes are both achieved and reported within the timescales of the programme, whilst allowing the project team to continue to develop their work.

Be clear about what you want in the final report

Reports of development projects have a particular purpose in mind, and staff may not be familiar with this kind of writing. They either lean towards a progress report or towards an academic publication. This is not what is usually required. The final 'report' needs to explain what the project set out to achieve and how it did that. It needs to provide evidence to the reader that the development is worth disseminating and needs to provide sufficient detail for an external reader to adopt or adapt the practice. To that end, again, a template is useful, but needs to be supplemented by brief guidelines on writing the report.

Provide support in writing the report

This can amount to a considerable effort, but is necessary to ensure that outcomes of the highest standard are delivered. Whereas the author should be allowed to write their own report without unnecessary intervention by the funding team, the report submitted should be seen as a first draft that is reviewed and feedback should be provided to help the author to improve the report. This of course adds to the time and effort taken to complete the report and this needs to be allowed for in setting out conditions, timescales and milestones for projects.

Be clear about who 'owns' the report

The project leaders are the authors of the report and clearly they will have ownership of the content. However, you may wish to publish the report in some form, whether that be web-based, electronic or on paper. You may also wish to publish summaries, abstracts or other derivatives of the work in order to maximise the benefits to the community you represent. It is therefore important to be clear about the copyright conditions pertaining to the works before they are submitted to you. As the funders, it is probably sensible to ensure that you own the work and are in a position to be able to publish it, either in full, or in summary, and any derivatives of the work that you feel are useful to your cause. To that end, be careful about how you stipulate the copyright conditions. If you choose to use Creative Commons licensing in order to allow for the widest possible dissemination, you need to consider carefully which version you choose. You should try to put yourself in a position in which you do not need approval from the original authors to publish or use any part of their report

4 Important specific issues in developing an effective programme

Risk assessment

An otherwise well considered project can fall if the risks associated with the successful completion of the project are not considered. For example, a project may rely on gaining feedback from students, but it is often difficult to gain the support of students in activities such as focus groups. Similar difficulties can arise with external agencies such as the professional bodies or employers. These risks need to be considered and mechanisms derived for reducing both the risk and the impact of its realisation.

Exception planning

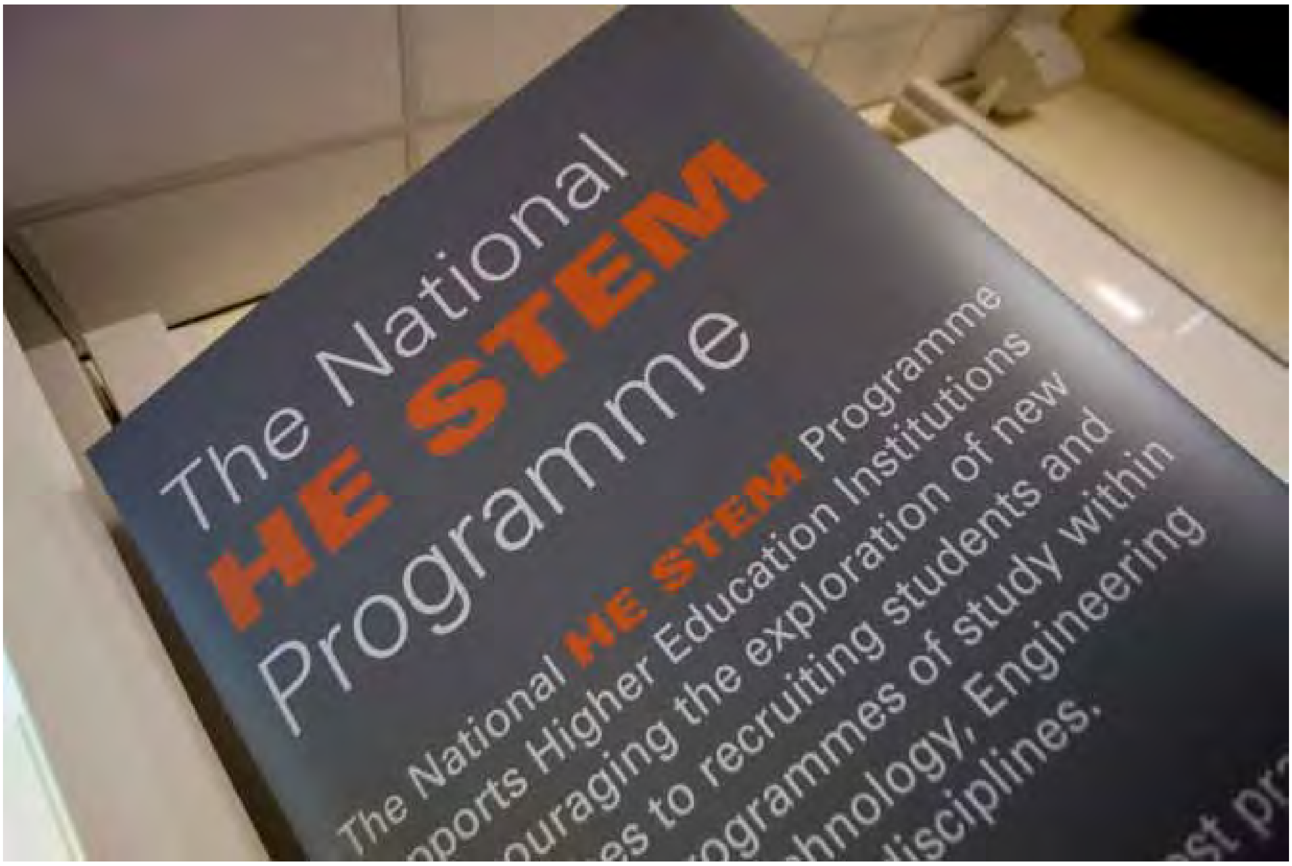
This relates to unforseen issues that may arise, but in some cases these can be anticipated and included in the risk assessment. For example, a project may require the involvement of an employer, and such an employer may agree to become involved. However, at the time of their involvement, their company may require their services, and they may not be available. In these kinds of exceptions, it is important to have a back-up plan available.

Team synergy

There is merit in involving several staff in a project. They will be able to discuss the project in more depth, workloads can be shared and cover can be provided if someone becomes ill or otherwise incapacitated. However, the involvement of too many staff can dilute a project and make it more difficult to manage. There is also a danger of partners 'bailing out' of a project or not fully engaging with it as required.

Dissemination

This is often misunderstood by many academics. They confuse dissemination with publication. Effective



dissemination begins at the start of the project. There are three phases:

dissemination for awareness
This involves staff not involved in the project, but close to it – say in the same faculty or in the same discipline in other institutions. Seeking their initial reactions to the premis of the project is an effective way of engaging them in the project at an early stage.

dissemination for understanding
As the project develops, it may be possible to deliver an internal progress seminar, involve staff in a focus group or seek their written feedback on progress. This will keep them aware of the project and help them to gain a fuller understanding of what you are doing.

dissemination for uptake
If the first two phases are exploited, then this phase is much easier and involves informing staff **and engaging** them in the outcomes of the development. This may require more than a publication of the project outputs, and may include developing resources and guidelines or even providing hands-on support for them in adapting your innovation.

Case Studies

Development and implementation of teaching aids to enhance the understanding of control systems

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A synopsis by the editorial team

Abstract

Existing educational resources for control systems have been refined and new resources have been developed. A new LabVIEW-based Control Systems Analysis Toolkit (CSAT) has been developed to assist lecturers in teaching control engineering and students to understand theoretical concepts. Specific manuals and activity exercises for the CSAT have been developed. Existing LabVIEW-based Process Control Virtual Laboratory (PCVL) educational software has been refined, together with a detailed hands-on laboratory activity manual. Existing Simulink exercises have been refined and specific video tutorials for the Simulink exercises have been developed. Evaluations have been conducted which indicate positive impact, and the resources have been made available to the control systems community.

All of the resources (Simulink video tutorials, the CSAT and the PCVL) can be downloaded from the "Resources" menu under the following link: **www.ilough-lab.com**

Keywords: open educational resources (OER), active learning, LabVIEW, video tutorials, control engineering

Control systems is a multidisciplinary engineering subject which is taught in electrical, mechanical, chemical and civil engineering degrees. Control systems subjects comprise a considerable mathematical portion which makes them less appealing to engineering students. One way to make control systems concepts more accessible to engineering students is by using computer simulations and interactive media. Matlab/Simulink and LabVIEW are two software packages that are used widely in control engineering for analysis, simulation and design of control systems.

Simulink provides a model-building environment that is graphical and more intuitive for engineers. Students can use Simulink to build control systems models, analyse them, change parameters and observe output behaviour graphically without the need to solve mathematical equations analytically. Matlab/Simulink in particular has been used in academia for the teaching and learning of control systems

LabVIEW provides a sophisticated environment for developing user-friendly engineering software tools and stand-alone executable applications that can be run without the need for installing the main development environment. This is not the case for Matlab/Simulink. Despite its fruitful characteristics, LabVIEW applications in teaching and learning in engineering (including control systems) are significantly less noticeable than those of Matlab/Simulink. LabVIEW can be used for developing stand-alone virtual laboratories and software analysis tools for control systems and has been used in the Department of Chemical Engineering at Loughborough for developing a Process Control Virtual Laboratory that demonstrates different concepts of PID control using a tank level control experiment.

Interactive teaching aids (e.g. computer simulations, interactive video tutorials and virtual labs) can have a positive impact on engineering students' attitudes and learning outcomes. This can be explained from many perspectives. According to the dual coding theory of *information cognition*, the human mind perceives and stores verbal and visual information through two distinct channels. The implication on educational processes is that incorporating visual objects with a written text (e.g. the lab manual) can lead to better learning. The *VARK learning styles model* suggests that there are four main learning styles: visual, aural, read/write and kinaesthetic. Learning from written materials such as lecture notes and lab manuals may be suitable for those students who have a strong read/write learning style. However, combining the computer simulations and/or virtual with written materials accommodates those students who have visual and kinaesthetic learning styles. The *learning pyramid model* suggests that information retention rates are different depending on the learning method (5% lecture, 10% reading, 20% audio/visual, 30% demonstration, 50%

discussion group, 75% practise by doing, 90% teaching others). Computer simulations and virtual labs provide the opportunity to learn by doing and hence result in much higher knowledge retention. Such interactive teaching aids are normally in an electronic format, enabling them to be used by other academics and students. Such open educational resources reduce redundancy and increase sustainability, since many educators and students are able to use current material and customise it to their own needs. They also minimise costs by reducing the time invested in developing resources from scratch.

The main objectives of this project were:

- to develop LabVIEW-based new educational software (the Control Systems Analysis Tool) to help students to understand essential concepts in control engineering
- to integrate and refine current resources (Simulink exercises and the Process Control Virtual Laboratory)
- to develop associated material and activities (e.g. videos, manuals and assignments).

Control Systems Analysis Toolkit (CSAT)

The main objective of this project was to develop LabVIEW-based stand-alone educational software to assist in the teaching and learning of control systems concepts. This is known as the Control Systems Analysis Toolkit (CSAT). The kit can be installed and run on stand-alone PCs without the need for LabVIEW or Matlab/ Simulink development environment. The user can perform a number of typical control systems analysis procedures with the CSAT (e.g. stability detection, time analysis such as impulse and step responses, poles and zeros calculation, Bode analysis, Nyquist analysis, Nichols analysis and Root Locus analysis). These procedures can be applied for nine typical control systems transfer functions: 1) Plant, 2). Actuator, 3). Controller, 4). Disturbance, 5) Sensor, 6) Open-Loop with measurements, 7) Open-Loop without measurements, 8) Servo Closed-Loop and 9) Regulatory Closed-Loop.

The CSAT is designed to be used by students and lecturers for enhancing conceptual understanding of control systems topics. Students can use it to test theoretical concepts taught in lectures and lecturers can use it in the classroom for interactively displaying theory while lecturing or as a platform for designing assignments or virtual laboratory work to accompany their modules. Active learning exercises have been designed to enhance students' conceptual understanding of key aspects of control systems.

Deployment of the tool into teaching and learning took place during the academic year 2011/12. Prior to this, students were asked their opinion about providing stand-alone software for analysis of different aspects of control systems and were very positive about being provided with such a tool.

Simulink exercises and video tutorials for control systems

Simulink for control systems is being taught within the level 6 *Chemical Process Control* module in the Department of Chemical Engineering at Loughborough University. Students use Simulink to build control systems models and analyse their behaviour. The aim is to finalise a number of Simulink exercises within two hours of supervised activities in the department's computing laboratory. Due to time restrictions, the objective was to develop video tutorials on how to work out the Simulink exercises, providing the students with assistive learning tools to be used at their own pace. Video tutorials were developed with Camtasia, a software tool for creating interactive video demonstrations. Educators can use Camtasia for capturing desktop screens or in association with PowerPoint presentations to develop customised videos. The Camtasia environment enables the developer to gain access to a number of capabilities/ functionalities, such as creating tables of content, adding 'call outs' and descriptions, audio and video editing, interactive multiple choice questions with feedback, connectivity to virtual learning environments such as Moodle, and final production of the video in various off- and online formats.

Seven video tutorials for Simulink have been developed, the first aims to briefly introduce the Simulink environment to students while the remainder cover six Simulink exercises. These exercises aim to help students use Simulink for enhancing conceptual understanding of dynamics and PID control. Each video tutorial has been supplemented with explicit objectives at the beginning and final conclusions of what has been covered, plus the general aims of the next tutorial. Comprehensive interactive descriptions have been added throughout each tutorial using the 'call out' feature of Camtasia. Most of the video tutorials have been associated with additional interactive multiple choice questions to enhance the conceptual/procedural understanding of the demonstrated topic in the exercise.

Simulink laboratory sessions in the winter semester of the academic year 2010/11 were conducted for around 50 level 6 students. The students had to attend two one-hour scheduled sessions and submit a compulsory piece of Simulink coursework by mid-December. At the end of the course, a questionnaire was delivered for the students to evaluate the effectiveness of the video tutorials. They were asked a number of related questions and rated their response using a six-point Likert scale where 1=Strongly disagree, 2=Disagree, 3=Disagree a little, 4=Agree a little, 5=Agree and 6=Strongly agree. Overall the response was positive; the mean for all questions was considerably above the neutral point. The students found the Simulink exercises helpful in enhancing conceptual understanding of the taught topics (highest scored mean), motivating revision of the relevant theory and making the associated mathematics less abstract. They also wanted to be provided with additional Simulink simulations and exercises for self-learning and practice. One of the Simulink exercises introduced the practical procedure of tuning PID controllers using the Ziegler-Nichols method. The students found this exercise quite helpful for mastering the method (joint second highest mean score), which otherwise would not be adequately mastered by only reading the lecture notes. The students also valued the idea of incorporating theoretical lectures with simulation demonstrations to illustrate the presented theory (joint second highest mean score).

Videos of the *Chemical Process Control* module were provided to students to use online as an assistive tool for the two scheduled Simulink laboratory sessions in the winter semester of the academic year 2010/11. In the final module questionnaire, students were asked their opinion of the associated video tutorials. The students' responses were generally positive, with an average mean higher than the neutral point. Students found the videos helpful in preparing for scheduled sessions and for additional practice after the sessions. They found the videos helpful for revision of Simulink before preparing for the compulsory coursework. The videos' pace, description and multiple choice questions were found to be satisfactory. The highest mean of students' response occurred when they were asked their opinion on recording video tutorials of the lectures and making these recordings available online.

Students were also very positive about the idea of extra online multiple choice quizzes and feedback in relation to other concepts and topics of the module. Google analytics of the website of the video tutorials show two main peaks at 15 and 29 November (the scheduled Simulink labs). A considerable number of log-ins to the tutorials website were noted for the period 29 November to 13 December (the Simulink coursework submission deadline), indicating that many students returned to review the video tutorials during their Simulink coursework.

Feedback on the videos from an e-learning officer and Camtasia development professional from the Engineering Centre for Excellence in Teaching and Learning at Loughborough University and a representative of The Royal Academy of Engineering was very positive and constructive criticism has been considered by the project team in the final production of the videos.

The Process Control Virtual Laboratory (PCVL)

The Process Control Virtual Laboratory (PCVL) is educational software programmed in LabVIEW for demonstrating control systems concepts by manipulating a simulated model of a physical process. The software has been developed at Loughborough University to complement hands-on laboratory activities that are performed on an Armfield PCT40 experimental rig. The PCVL provides a virtual model of an Armfield PCT40 tank filling process, plus additional control and regulation capacities. The PCVL can be used generally by control systems students and lecturers as a virtual lab activity. Furthermore, those who have access to the Armfield PCT40 rig might find the PCVL a valuable addition to the physical rig. The main interface is designed to give access to four main experiments: level tank control, pressure control, temperature and flow control, and project work. Currently, the tank level control experiment interface is active while the rest are to be developed in the future.

The tank level control experiment is a typical process control engineering exemplar used in undergraduate control systems courses. A special and detailed laboratory manual for the tank level control experiment has been customised. The manual can be used for conducting an instrumentation and control experiment virtually via the PCVL and proximally with the Armfield PCT40 physical rig. The aim of the manual is to familiarise level 4 and 5 engineering students with the basic concepts of instrumentation and control concepts. The PCVL installer sets up both the PCVL software and the associated laboratory manual.

Earlier versions of the PCVL were originally developed and evaluated during the period 2007 to 2010. Virtual laboratories were used in a variety of pedagogical studies, mainly with level 5 students on the department's *Instrumentation and Control* module. A novel constructivist pedagogical model of laboratory education, whereby the virtual laboratory plays an essential component, was proposed. Using the virtual laboratory in preparation for a hands-on laboratory session has been found to leave a statistically significant positive impact on students' learning outcomes in pre- and post-lab tests, laboratory report quality and the module final exam.

In this project, a number of educational resources have been developed and made available online (together with existing materials). Overall, students have been generally positive about utilising the described interactive teaching aids. Engineering students are normally visual and experiential learners and these aids depend heavily on visualisations and provide a venue for virtual experimentation. This may explain the eager requests for more tools that cover other concepts of the taught material and also explains the enhanced learning outcomes. As for lecturers, the benefits include the time saved when developing effective teaching aids from scratch. There are institutional benefits to UK universities to be had from developing and making such resources available online, including enhanced student satisfaction and international marketing. Many international students worldwide can access and utilise quality materials. This could also work as an indirect marketing process; if international students have plans to continue further studies in another country they may consider a UK university whose tools they have already utilised remotely.

It is envisaged that additional resources for other aspects of control systems will be developed in the future and added to the current set.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/teaching_aids_of_control_systems.pdf**

Developing employer engagement in STEM through career mentoring

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A synopsis by the editorial team

Abstract

The Sheffield Hallam University Career Mentoring Scheme aimed to enhance the employability of engineering students by introducing mentoring partnerships between a student and an employer (i.e. a professional from industry in a job role/organisation that was of interest to the student). As students were mentored by experienced professionals from the workplace, the scheme enabled them to:

- research career opportunities
- create a network of contacts
- gain a better understanding of the typical tasks, requirements and expectations or job roles of interest to them and thereby enable them to make more informed career choices
- enhance confidence in/understanding of skills required in industry and how these can best be projected in job applications and at interview
- see the relevance of their studies in the workplace
- understand the role and value of professional bodies and the process of chartership and ongoing professional development beyond graduation
- develop their (inter)personal skills.

The scheme encouraged employer engagement by building links with alumni, professional bodies, employer networks and STEM Ambassadors.

Keywords: career, mentoring, professional development, career management, employability, engineering, maths, undergraduates, alumni, professional engineers, transferable skills, autonomy, university and industry partnerships

Sheffield Hallam University (SHU) Careers Service has been running a generic Career Mentoring Scheme for a number of years, initially as part of the *Impact Programme* (a career coaching and employability development scheme) which proactively targeted students from widening participation backgrounds. It was noticeable, however, that although the scheme had established a reputation within some subject areas and faculties, engineering and maths students had not actively engaged with it. HE STEM Programme support provided the opportunity to develop the scheme specifically for engineering and maths students, identifying appropriate industry-based mentors and tailoring materials specifically to the mentees.

Recent graduate employment data have illustrated the need for STEM departments in higher education institutions (HEIs) to do more to help students develop the necessary employability and non-subject specific transferable skills. One very important step that can be taken is to put students directly in touch with employers in the workplace. This project aimed to increase students' exposure to employers and enhance links between HEIs and industry.

The approach taken to setting up the Career Mentoring Scheme involved several phases: recruiting the mentors, recruiting the mentees, training and induction for participants, matching and monitoring the partnerships, a final "celebration event" and evaluation of participants' experiences.

Potential mentors were contacted/recruited using a variety of means, including email requests through university networks such as:

- the alumni association
- personal/professional contacts of the maths/engineering department's teaching team
- local employers from engineering organisations who had advertised vacancies and opportunities with the careers and employment service in recent years
- organisations who had attended engineering recruitment fairs run by the universities in Sheffield
- employers who have recruited placement students
- the university's pool of STEM Ambassadors.

Networks external to the university were also targeted with email requests. These included:

- the Chamber of Commerce
- posting messages on relevant LinkedIn discussion boards
- professional bodies who were approached to

circulate details of the career mentoring scheme amongst their regional membership.

Particular mentor requests from the students were also pursued. For example, where students wanted to target a particular organisation, the scheme coordinator "cold-contacted" organisations and/or encouraged and supported the students to take the initiative to approach organisations for themselves to request mentors appropriate to their choices.

All mentors applying to the scheme were met on an individual or group basis in order to find out more about their experience, background and expectations of the scheme.

In terms of mentee recruitment, the opportunity to meet with a mentor from industry was made available to undergraduate engineering and maths students in any year of study. It was envisaged that, as well as the generic benefits outlined above, level 4 students could specifically benefit from meeting with an industry-based mentor as they would have the opportunity to gain insights that would enable them to plan ahead and make the most of their time at university. It was also expected that the scheme would be useful to level 5 students who were preparing for placement or who wanted to get as much experience as possible before they entered the busy final year. For level 6 students, the scheme would help to explore options, consolidate placement experiences or enhance their CV and expand their network of helpful contacts. Sheffield Hallam is a very inclusive university so, whilst mentoring was offered to all students, it aimed in particular to attract applications from diverse groups of students, especially those traditionally under-represented in the workplace. Where students don't have connections in the employment sector to which they aspire, their ability to get valuable first-hand insights into the workplace is restricted, making it difficult for them to make well informed decisions about their future. The scheme aimed to extend to such students the opportunity for informal career planning advice.

Students were notified of the scheme in a number of ways:

- announcements were posted on the course virtual learning sites
- information about the scheme was included in start of year induction talks
- details were posted on the careers service vacancy website
- plasma screens and computer screensavers around campus had an "advert" about the scheme streamed to them
- the scheme coordinator went into lectures for targeted groups to give brief presentations about the scheme and the mentors available
- the placement team posted details on their virtual learning site
- course tutors were emailed about the scheme and

choices of mentors available so that they could refer students to the scheme if appropriate.

Students applied to the scheme using an application form on which they identified the type of mentor required, explained their reasons for applying and what they hoped to gain from taking part and identified what they had done so far to pursue their career ideas and any challenges they felt they faced in the job market. All applicants were then invited to an interview where their expectations of the scheme were discussed in more depth and mentor preferences shortlisted. The interview was arranged not only to test the students' motivation, time management and communication skills, but also to clarify their understanding of the requirements and commitments to the scheme, to identify/expand their objectives from meeting with a mentor and to ensure that their expectations were realistic.

A mentoring induction event for both mentors and mentees was then arranged. This event ensured that participants were clear about the commitments and expectations of the programme, that they understood the boundaries and ground rules of mentoring and had the chance to practice some mentoring skills. The event also provided an opportunity for informal networking where students could meet mentors and potentially find a match suitable to their own requirements. Those joining the scheme after this launch event had a one-to-one "preparation for mentoring" meeting as part of their interview for the scheme and selected their mentor based on the information provided on the mentor's application form and information gained by the scheme coordinator during the mentor's induction meeting.

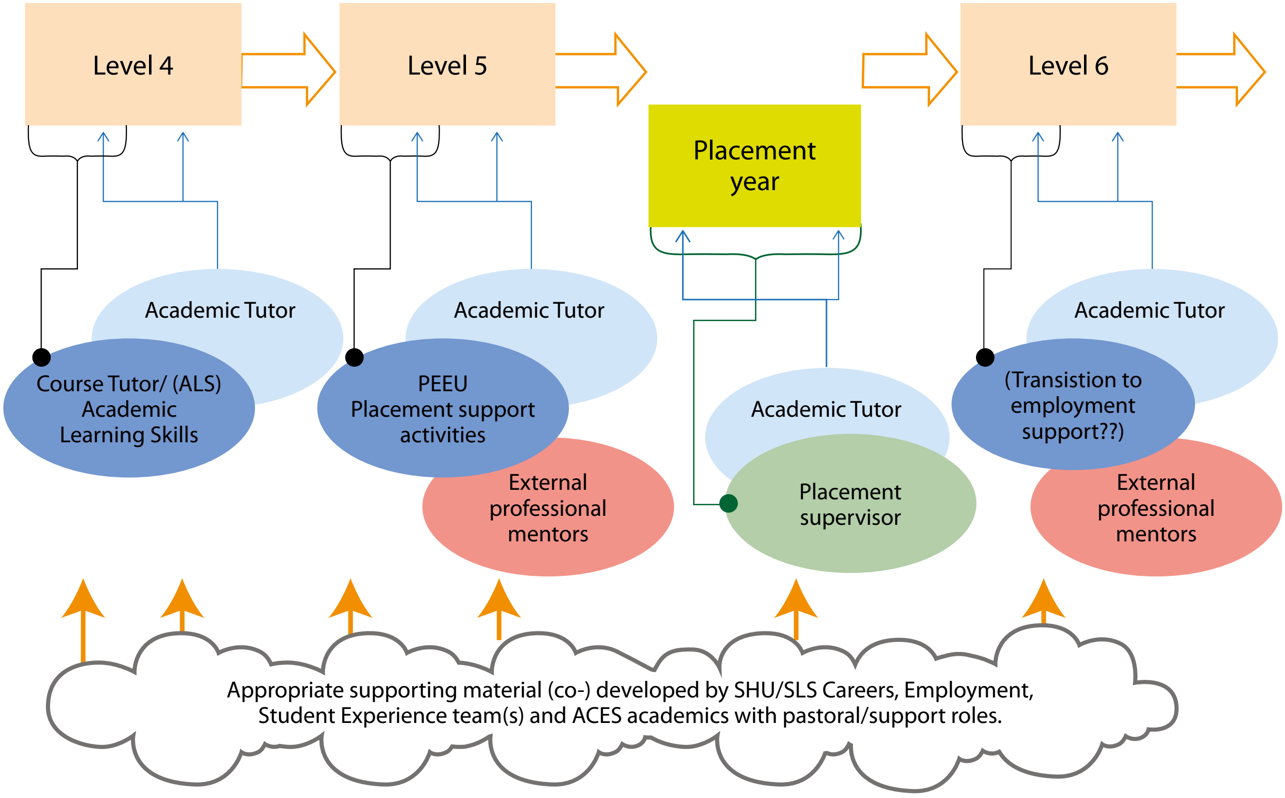
It was suggested that the students should arrange to meet their mentor four times over the duration of the academic year. The students were encouraged to take the lead in the partnership, identifying their objectives, negotiating the agenda with the mentor, organising and making notes of the meetings and following up on any action points agreed. By taking this proactive role, it was expected that the students would not only gain valuable insights into a job role, but also develop their personal and professional skills. Supporting framework material, including a mentee journal and a mentor "essentials pack", was provided to all participants and included suggested agendas, action plans, objective-setting exercises and a skill development journal where students could record their personal and professional development learning process. This approach was designed to prepare them for future professional development activities and the process of gathering the evidence required when working towards Chartered Engineer status.

Once mentoring partnerships were introduced, they were on the whole "left to get on with it" and monitoring of partnerships was kept to a minimum in order to encourage the students to be autonomous learners. Feedback was requested after the mentoring pair's first meeting in order to confirm that they were satisfied with the allocated match and were happy to proceed. They were also invited to an optional mid-way review and an informal networking event which was an opportunity to share ideas and demonstrate materials and resources available in the careers and employment service that could support the mentoring pair in meeting their objectives. A monthly email with a mentoring "top tip" was sent to students to maintain contact with them and suggest ways in which they could continue to make the most of the opportunity and maintain the momentum of their mentoring partnership. It was also an opportunity to pick up on any issues arising that needed to be addressed or find out about students' achievements along the way.

A celebration and evaluation event was arranged for the end of the scheme in order to provide the opportunity to review the experiences of both mentors and mentees. This included completion of evaluation questionnaires by all participants. Mentees were also asked to submit a summary report reflecting on their experience, the skills gained, their insights into their own personal and professional development and any future actions they were going to take following the mentoring experience. Feedback gathered from both mentors and mentees through the reports, meetings and questionnaires was very positive and all participants acknowledged that career mentoring provided valuable experience and contributed to employability development initiatives for engineering and maths students.

Choice of the mentor was noted as one of the most important factors that determined the students' recognition of the benefits of the scheme. Although most mentors felt able to help students across engineering disciplines and felt they were able to offer objective and practical career planning and job search support, in general students requested mentors that had a direct match to their career aspirations, preferring to have no mentor at all rather than what they considered to be a "generic" career mentor. Providing information on the background/experience of the mentor is essential in order to help the student make informed choices. Students liked to be involved in the choice of mentor. In the selection interviews they had the opportunity to shortlist and prioritise the mentors that most appealed to them, and the induction event also provided opportunities for mentors/mentees to meet informally and identify a mentoring partner with whom they would like to work. Several of the mentees identified the mentor of their choice in this way.

Face-to-face meetings were valued by the mentees as most effective for professional relationship building, especially when mentees gained access to the mentor's workplace, had the opportunity to meet colleagues, attend events with their mentor, gain insights into the work culture and even shadow or gain work experience.



Holding the training and networking event off-campus at a mentor's offices also helped to create the professional "standard" and expectation of the scheme, with students being introduced to business etiquette and workplace culture, amongst other things. One development for the future could be to explore other mechanisms by which mentoring pairs could work together (for example, "virtual" meetings using Skype). This would have its limitations, but could expand the range of mentors that could be recruited to the programme and help international students wanting to generate contacts in their home countries. Establishing an email mentoring scheme is another option, as this could mean that contact could be arranged to fit in more flexibly within the students' limited availability. It would mean, however, that some of the more transferable skills that face-to-face mentoring would support may not be developed.

Partnerships that were not maintained over the academic year were mainly as a result of poor time management and the student not being able to cope with the pressures of work and study. However, in one case this realisation was not entirely without benefit when the student recognised that valuable lessons regarding professionalism and time management had still been learned.

According to those who expressed a preference, level 5 was considered the ideal time to embark upon career mentoring. However, the scheme received applications from students in all years and this emphasised the need to not restrict the scheme exclusively to level 5 students, but to keep the offer of the mentoring scheme open to students for whenever they feel ready/able to consider career planning.

Although the scheme ran from November to May within the academic year, some mentoring pairs were not matched until January/February, thereby restricting the time available for them to meet during the remainder of the academic year. One possibility is to encourage earlier application to the scheme (i.e. at the end of one academic year in preparation for the next). Alternatively, it may be possible to offer the scheme around the year on a "roll on, roll off" basis and across summer vacations. This would add flexibility for the students and could mean that more would be able to take part and benefit from the experience without increasing the number of mentors.

Offering the career mentoring scheme across all engineering disciplines presented a challenge, as this meant that a wide range of mentors had to be found appropriate to the career aspirations and course backgrounds of students in areas as varied as electronics, aerospace, mechanical renewable energy and power engineering. It also meant that some mentors had volunteered their time by applying to the scheme but were not selected as a mentor and matched to a student. Managing the expectations of all participants was therefore paramount and maintaining relationships with mentors was important in order to sustain their commitment and support. A future development of the scheme will work with specific targeted course teams in order to ensure that the availability of mentors reflects the career aspirations of the students. That said, some mentees recognised that the suitability of their mentor and the basis for making the match of mentor to mentee could be based upon many criteria, not just career path.

Although post-intervention feedback from participants was generally very positive, raising awareness of the scheme amongst engineering students and staff in the first instance was challenging, despite widespread publicity using a variety of means. Face-to-face direct promotion by presenting the scheme during lectures or meeting staff individually to explain the mentoring opportunity to them proved more effective than email and other "virtual" methods. The reputation of such a scheme builds up over time and students prove effective advocates; hence it is important to establish case studies and encourage scheme ambassadors to help to promote it.

In the current economic climate and in a region where the majority of engineering firms are small and medium sized enterprises, contacting companies speculatively in an effort to recruit mentors from engineering companies or specialisms also proved challenging. Instead, sending publicity via connections with professional bodies proved more effective for gaining recognition of the scheme amongst their membership and recruiting mentors (mentoring activities within professional bodies are a well established career development activity). Establishing more formal affiliations and partnerships with regional networks via professional bodies is to be encouraged. Similarly, by establishing formal recognition of the experience for mentors and their organisations in terms of volunteering their time, it is possible to try to offer something in return for mentors' involvement and aim for a "win:win" relationship for all participants (for example, formally establishing that mentors can gain Continuing Professional Development (CPD) credits from involvement and ensuring that new graduate mentors are aware that the mentoring experience constitutes as evidence they can use in their portfolio of evidence for Chartership). Approaching companies with whom the university already has established contacts and "warm leads" proved an effective mechanism for recruiting mentors, with STEM Ambassadors, placement providers and companies known to recruit graduates from the university being the most effective recruitment channels. Offering mentoring as a low-risk, cost-effective way for a company to establish and maintain links with the university and academic community proved effective.

In terms of integration and sustainability, a steering group was established comprising staff from the careers service, placement team, maths and engineering academics, a student representative of the IMechE and a representative of a local Russell Group university's Engineering Gateway.

Irrespective of the type of institution, strategies for sustainability were common. It was identified that, to ensure it was sustainable and became embedded within general practice, the scheme needed to be integrated within the "student journey" so it was clear to all parties where it fitted within a bigger framework and in the context of other activity both within the course and the university. The "topography" of students' learning was plotted and the inter-relationship of all the parts and the relationship to mentoring for different stakeholders was clarified in a series of diagrams. Sustainability beyond the course or faculty structure was also secured when mentoring was written into the university's Access Statement as a means whereby students from diverse backgrounds could be offered additional employability support. This confirms its longer term continuity and demonstrates the university's commitment to developing and integrating it further.

The creation of diagrams of the student journey which mapped out the contribution of various academic and extracurricular activities and how they fitted within the context of the students' experience and their development of personal/professional skills had a wider relevance beyond the faculty. The outcomes of Steering Group discussions and resulting "visual aids" have subsequently been presented to committees within the university and are now contributing to informing university-wide practice on student support Personal Development Planning (PDP) frameworks. This collaboration between the Careers and Employment Service (a central university service) and colleagues within the faculty has provided a conduit for learning from a faculty context to be presented to a wider audience and which will contribute to university-wide action groups.

Collaboration between the faculty and the central Careers and Employment Service has led to other valuable learning outcomes which can inform future development. The Careers and Employment Service has worked over a number of years to establish its generic Career Mentoring Scheme and, although having been successful in its task (introducing over 100 mentoring partnerships in an academic year), has worked in relative isolation for most of that time. Establishing a Steering Group for the purposes of this project has been invaluable for identifying a plan that integrates the scheme within the fabric of the faculty, helps to identify key influencers within the faculty and, at course level, has helped to get the scheme included in a number of faculty events (such as an Industry Day and Engineering Conference) and involved in developing a Women's Engineering Network. Having the insights and influences of colleagues within the faculty has helped to identify more appropriate communication mechanisms through which it is possible to promote the scheme, generate appropriate referrals into the scheme, recruit mentors and build on existing industry relations and alumni networks. This is a learning outcome that the scheme will adopt on a wider basis when expanding its outreach into other subject and faculty areas.

For future development, there are discussions to ensure that the Career Mentoring Scheme is:

- integrated within the *Academic learning support process* for level 4 students. This academic support module "inducts" the student into university life and encourages them to see their course within the context of the university and the wider industry. The mentoring scheme will therefore be introduced to students towards the end of this level 4 module when they could be encouraged to apply in preparation for level 5
- presented to level 5 students during placement preparation modules undertaken by all students. It would be explicitly offered to complement the placement search process
- offered to all students who did not secure placement so they have an alternative opportunity to gain an insight into the workplace and to establish a professional network. Other level 6 students returning to university following placement would be offered the mentoring opportunity in order to help them "debrief" from placement and prepare for the graduate job search.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/employer_engagement_in_stem.pdf**

Higher (University) Apprenticeships in engineering technology: SME employer model

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A synopsis by the editorial team

Abstract

This project developed a model for collaboration between higher education and small to medium sized enterprises. The scheme presented a variation of the Higher Apprenticeship model, offering employers the opportunity to work with undergraduate engineering students on short-term projects whilst training was undertaken through a university-led programme of activities. Collaboration was encouraged by managing the perceived areas of risk (namely the application process, preparatory training and managed mentoring), allowing the employer the freedom to focus on the project activities.

Feedback from the participants was used as a basis for enhancements to the curriculum and the continued development of the project.

Keywords: Short-term placements, SMEs, Higher Apprenticeships, employability

Established as the Borough Polytechnic Institute in 1892, London South Bank University (LSBU) has focused on providing professional opportunities for all who can benefit for well over a century. This pilot continued in the same vein by aiming to provide small to medium sized enterprise (SME) employers with students who had recently acquired valuable skills as part of their academic studies along with an ability to solve "real-world" problems with a degree of autonomy. The students would equally benefit by developing their understanding of possible future career paths whilst gaining valuable employment experience. The issue of the employability of graduates has received much attention from the media, employers and government agencies, highlighting the importance it plays in improving economic growth and the considerable positive benefits to all stakeholders involved in work placements concur with the experiences of academics at LSBU, particularly for courses where the ethos of placements is firmly embedded in the curriculum. With the aim of enhancing the curriculum, courses were chosen where the take-up of placement opportunities needed addressing. These courses (namely the BSc (Hons) Mechanical Engineering Design (MED) and BSc (Hons) Computer Aided Design (CAD)) had an even balance of theoretical and project-oriented modules.

The aims of the project were achieved by identifying SMEs with short-term engineering projects that could be undertaken by five appropriately skilled students during the summer recess period. The placements ran over two summers, enabling the students to experience different roles. An NVQ scheme was selected to run in parallel with the placement programme, with training and support provided by the support tutor and an NVQ assessor. This methodology would be tested and the lessons learnt disseminated to help inform policy and support for this type of learning model.

Whilst developing the template for working with SMEs, it was noted that many issues were linked to the uncertain economic climate. With highly skilled staff undertaking tightly defined tasks within limited margins, some felt there was little room to accommodate a training programme. Several SMEs had been involved in some capacity with further education (FE), but collaborations with higher education (HE) were relatively unknown. This was overcome by focusing the initial contact on developing an understanding with the employer and identifying a definite need for the placement in relation to their business. Several of the initial employer discussions for this pilot highlighted that previous experiences of training schemes had left a negative impression, thus a consistent theme in the early stages of this project was the responsibility of the academic in terms of "proving the worth" and developing the partnership.

There was concern that the fast-paced, lean structure of the SME environment might not be suited to the type of schemes successfully employed in larger organisations. However, it was hoped that the evidence-gathering process associated with the NVQ would be flexible enough to fit into the wide range of environments that might be encountered and a "light touch" approach was taken in both the initial meetings and interim communications.

Both a skills management workshop and the initial meetings with the employers were used to develop an understanding of the scheme, whilst emphasising the urgent need to acclimatise to their environment. Based on a self-assessment of their working environment, the students were given responsibility for selecting the NVQ modules.

Determining a valid and immediate employer need was considered central to the success of the project. Clearly, this could only work if the employers were sufficiently convinced that the training element would not be a burden on their day-to-day operations and that the proposed students would be a valuable asset for the period of the placement. These objectives were broadly achieved by splitting the activities into areas discussed below.

It was recognised from the outset that, due to the highly specialised nature of each enterprise, finding a group of employers in the SME sector would be challenging. The sector skills council SEMTA, with significant experience of working with a broad and diverse range of employers, was able to provide advice on successful schemes and highlight the type of skills which would be valuable to prospective partners. They also advised on ways in which the lessons learnt from large scale projects were scalable to smaller schemes.

With respect to identifying the partner employers, a template for commonality was proposed, with the ideal partner fulfilling the following requirements:

- Technology-focused, utilising procedures and processes that could be aligned with existing programmes at LSBU
- Sufficiently structured to provide appropriate supervision and a meaningful programme for the period of the placement
- A clearly identified need (ideally a role for the student or a project) whereby a sufficiently skilled individual would be able to add value to the company business
- Appropriate health and safety measures in place in line with guidance from the LSBU Employability and Careers Service team
- To improve the student experience, a travel zone for each student was defined, only selecting companies within reasonable commuting distance that matched their skill set.

The resulting identification process was the result of lengthy research, numerous telephone calls and previous contacts. During this process the following observations were made:

- SMEs contacted were keen on the idea that students would be interviewed and matched to their needs by the university, as this was seen as a resource-intensive process with a high risk of recruiting the wrong type of student
- A recurrent theme amongst employers was the perceived lack of employment skills and awareness of "the world of work"; they liked the idea of students attending a skills management workshop in advance of the placement, as well as them being on courses with a high practical component
- A three-month placement was easier to commit to for a defined short-term project.

In terms of maintaining flexibility for the scheme, it was agreed that the employers would pay an allowance to cover the students' travel and subsistence. This also made it possible for them to discuss the duration of the project in terms of work hours. It should be noted that the participating employers were able to go beyond minimum expectations and agreed competitive pay packages.

Initial conversations with the prospective employers revealed much in terms of their expectations. The most common requests were:

- The student would need to be sufficiently independent to follow instructions without the need for very closely monitored supervision
- The student would need to be an excellent communicator, being work-aware and ideally with previous employment experience (experience in the same sector was not required; however, the discipline instilled in all employees was considered vital)
- The scheme should not negatively impact on their business.

These requests became key considerations when selecting the students, as each employer was given the opportunity to scrutinise the selected candidates' CVs and interview them in order to determine suitability.

As the cohort of participating students had already been identified, the selection process focused on a written application which was intended to tease out a range of qualities in the applicants that would be valuable to the employer. Three students were selected from the BSc (Hons) MED and two from the BSc (Hons) CAD. The target cohort (level 5 full-time undergraduates) had just completed two relatively complex design projects, so there was an expectation that they would be ready to apply this knowledge in a work-based environment.

The initial training was preparatory, with the following series of workshops and seminars being implemented before the interviews and in advance of the actual placements:

Management skills workshop: Run by the Careers and Development team at LSBU to develop the candidates' understanding of what employers expect in terms of business etiquette, communication and levels of responsibility. This was also a good opportunity to manage the students' expectations of the pilot programme and gauge their opinions of the scheme from the outset.

CV preparation and "mock" interviews: As the intention was to match each of the five students to an employer, they needed to undergo an interview to confirm their suitability and discuss with the employer the nature of the roles. It was critical that their CVs clearly communicated the required information, whilst being appropriately presented.

Training: A key objective of the training aspect of the scheme was to provide a series of evidence-based competencies that could be assessed in the workplace. The level of these acquired skills was set at level 4 to allow the candidates to reflect on their academic studies, recognise the relevant "real-world" scenario and demonstrate appropriate competency. It was felt that the NVQ programme structure would provide sufficient flexibility for students in different roles, in consultation with the assessor, to select a framework of modules that matched their own role. Colleagues at SEMTA had undertaken a comprehensive study of Higher Apprenticeships in engineering and technology in 2008. Elements of the model proposed therein were adopted for this scheme. The qualification being sought as part of the pilot was the EAL NVQ Level 4 in Engineering Leadership. It was anticipated that the participants would achieve this award at the end of the second placement.

With respect to developing an individual learning and assessment plan in agreement with all stakeholders, the initial plan stated that an LSBU academic would take on the role of assessor for the scheme; however, the registration and training required within the timescale of the project made this impractical. The alternative approach saw the outsourcing of the NVQ training and assessment element to a service provider who ran a two-hour workshop outlining the ethos of work-based assessment, methods of evidence acquisition and the reflective nature of the NVQ scheme.

At the outset, assessment of student progress would be measured against attainment of agreed NVQ modules during the first cycle of the project. This element of the scheme did not work as anticipated because of the shorter than expected duration of the placements. The focus of the assessment thus reverted back to the experiences of the students and employers at the end of the placement terms, with comparisons being made with their expectations at the outset of the scheme.

The project was scheduled to run in two cycles in order to give each student the opportunity to experience a broader work experience. This made the evidence-gathering process required by the NVQ less obtrusive in terms of daily operations. This approach would also allow the feedback to inform the setup and implementation of the second placement for each student. To this end, it was important to get the most direct feedback possible from all of the stakeholders.

Neither a paper-based evaluation questionnaire nor lengthy interviews would elicit sufficiently critical opinions of the project, so each of the students had an informal face-to-face interview and a series of employer interviews were conducted via telephone. The student interviews were held first to help put the placement into context and avoid background questions being asked in the employer interviews.

Student feedback

All of the students felt that they were given a degree of autonomy in their respective roles.

The variation in length of the placements meant that those on longer projects felt more able to adjust to the work environment. The perceived value of the experience also varied depending on the roles, but a common theme was a greater appreciation of the need to communicate effectively, prioritise personal tasks and manage time.

The students responded positively to working in different environments, emphasising that they had a better idea of what they wanted to do after graduation and, in some cases, were considering new directions. The experience left them with a greater sense of urgency with respect to their final year studies, in particular the planning of the final year project.

They felt that the technological aspects of their degree programmes had prepared them sufficiently well to deal with the projects and commented on how much of the work observed was underpinned by taught principles.

The students responded positively to the workshop sessions, commenting on the difference between their perceptions of their readiness and the adjustments that needed to be made. They were satisfied with the level of support and communication, particularly in the early phases of the project, but felt that the actual placements should have been confirmed earlier.

The group responded well to the online communication used in the NVQ assessment process, but were less comfortable with the evidence-gathering process. They felt forced to prioritise their work-based objectives over the NVQ to ensure that the placement was successful. This did not seem to match their expectations of degree level study, with some commenting that course-based training might work better.

In terms of the benefits, their overriding view was an understanding of greater professionalism and the role of effective communication. All of the students commented on their sense of pride in completing a variety of valuable tasks.

Employer feedback

In general, it was felt that the students fitted well into the organisations and demonstrated a willingness to learn; however, it was noted that there was a need to change their mindset from being students to becoming employees in terms of focus and time-managed delivery.

The responses to adding value varied according to the type of role, but the range of comments highlighted the confidence in the students' abilities, particularly where opportunities were taken to modify and develop roles as a result of the students' input.

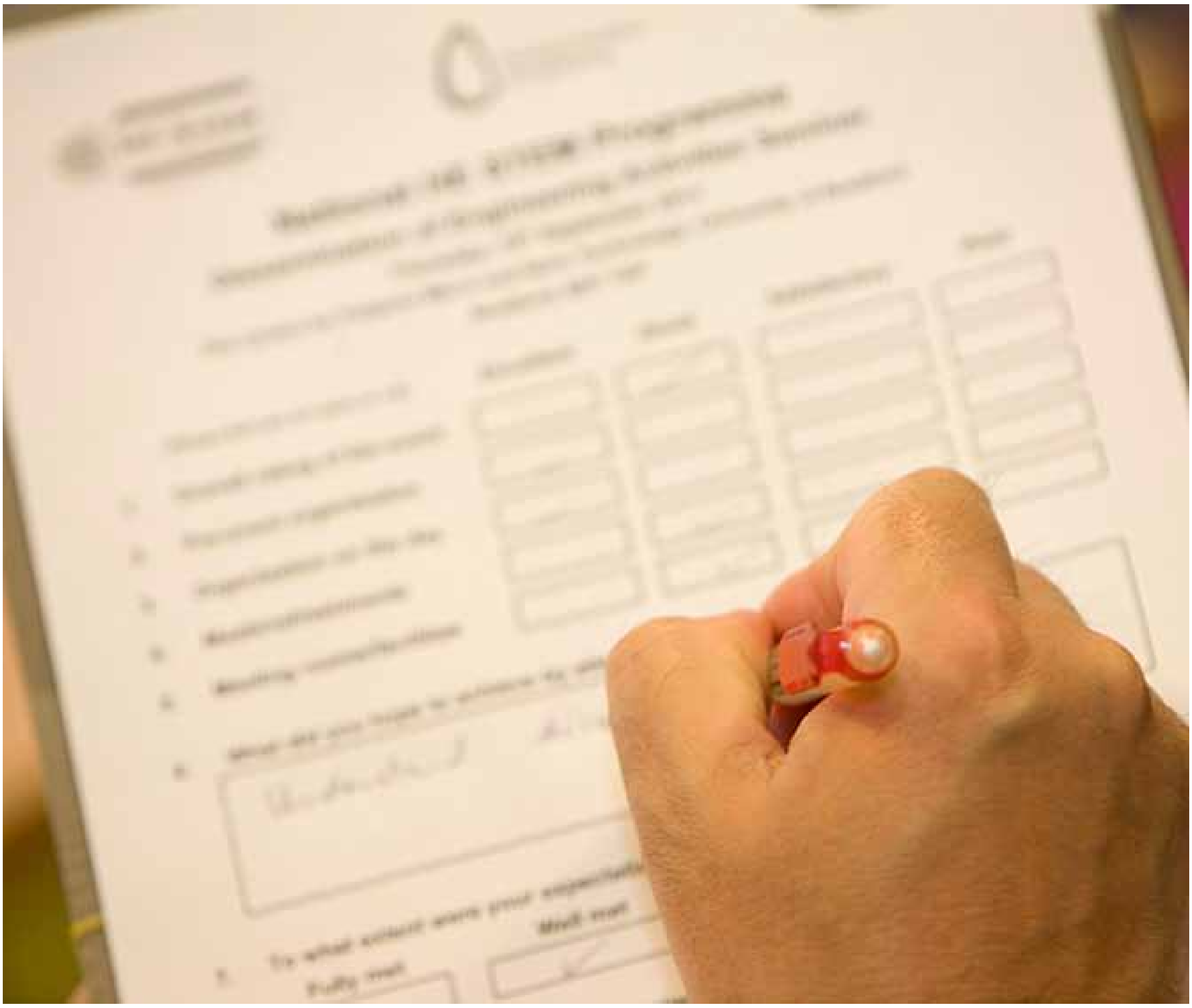
The employers understood the role of the NVQ, but did not feel that the structure suited their mode of operation. Several felt that an initial briefing meeting for the NVQ, well in advance of student involvement, might have helped them to better integrate this into the placement activities.

The employers were positive about the scheme and the added value to the student. Some felt that the programme would be improved by extending the length of the placement. There were several comments advocating an industry perspective as part of the degree programme to help prepare students for the work environment.

In conclusion, the biggest challenge for this project was securing the placements. The economic climate has caused companies to look at staffing efficiencies, with implications for investment in training programmes.

Several of the companies contacted were concerned that the responsibility for the student would fall entirely on their shoulders. Further discussion highlighted that, whilst many were keen to see an influx of skilled staff, general opinion was that educational programmes seemed to leave students ill-prepared for work. This led to genuine surprise that these students could add value to their organisations. Many of the SMEs contacted had been exposed to training schemes through FE but had had little or no contact with HE. In many cases, this proved to be a barrier that could only be overcome by developing confidence through longer-term partnerships between the organisations.

The process of recruiting a permanent employee is costly, but this is balanced by the benefit of finding the "right person" for the job. The risks were seen as being far too great for a short-term project undertaken by an "unskilled" trainee. The model proposed here sought to remove these concerns by managing the selection and matching process



for the role. Whilst the companies preferred this approach, the students felt somewhat alienated from the process. In future, students will be involved in the process of finding an employer that fits the project criteria and matches their individual skill set.

The difficulties in securing employers impacted on the duration of some of the placements, so it was difficult to judge whether extending the project duration beyond three months was necessary, although the more design-oriented projects coped well with this limit, with one employer extending the duration of the placement. This flexible approach was welcomed and in keeping with the spirit of the programme.

The NVQ programme did not work as well as anticipated. Feedback from all participants showed that this needed to be embedded at a much earlier stage, so consideration will be given to whether preparatory work can be integrated into the curriculum. Despite the structure of the modules and the closely managed relationship between the assessor and the students, employers felt that it was disjointed and un-associated with their work; students similarly found it an unfamiliar system and did not feel able to dedicate sufficient time to the evidence-gathering process. There is clearly a need for supplementary training; however, this needs to be explored in the context of the SME's needs as well as those of the student.

It has been observed that there is a marked difference in the approach of the returning students when compared to their peers. Their experiences have had a positive influence on the second cohort who now consider this an ideal way to gain experience without impacting on the overall length of their study programme.

The second cycle of the project is well under way for the initial group, with many of the recommendations implemented. Work is ongoing to create a hub for closer collaboration with appropriately aligned SMEs. Progress on both aspects will be documented for further dissemination.

The full case study and literature references can be found at:
www.hestem.ac.uk/sites/default/files/higher_apprenticeships.pdf

The development of a small-scale geotechnical teaching centrifuge

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A synopsis by the editorial team

Abstract

Geotechnical engineering is a core discipline within civil engineering that supports the infrastructure development which underpins modern society. The simulation of realistic geotechnical design at undergraduate level is often restricted to routine calculation-based methods reinforced by simple element laboratory tests which fail to provide a holistic learning experience. Using the latest research techniques, laboratory teaching can now offer the opportunity for students to test small-scale physical models which are representative of larger real world full-scale engineering problems. To provide greater connectivity between geotechnical theory and design, a small-scale 1.1m diameter teaching centrifuge has been developed. This enables observation of the behaviour of small-scale models tested under increased gravity to be directly related to full-scale field conditions. Accompanying educational resources have also been developed. An additional core objective was to promote widening participation amongst other higher education institutions and this has been achieved by ensuring that the centrifuge is highly cost-effective, built from standard off-the-shelf parts and features supporting documentation in the form of a "*how-to*" guide which details the centrifuge design, engineering drawings and the manufacture and installation process for technology transfer.

Keywords: experiential learning, geotechnical design, civil engineering, activity-led learning

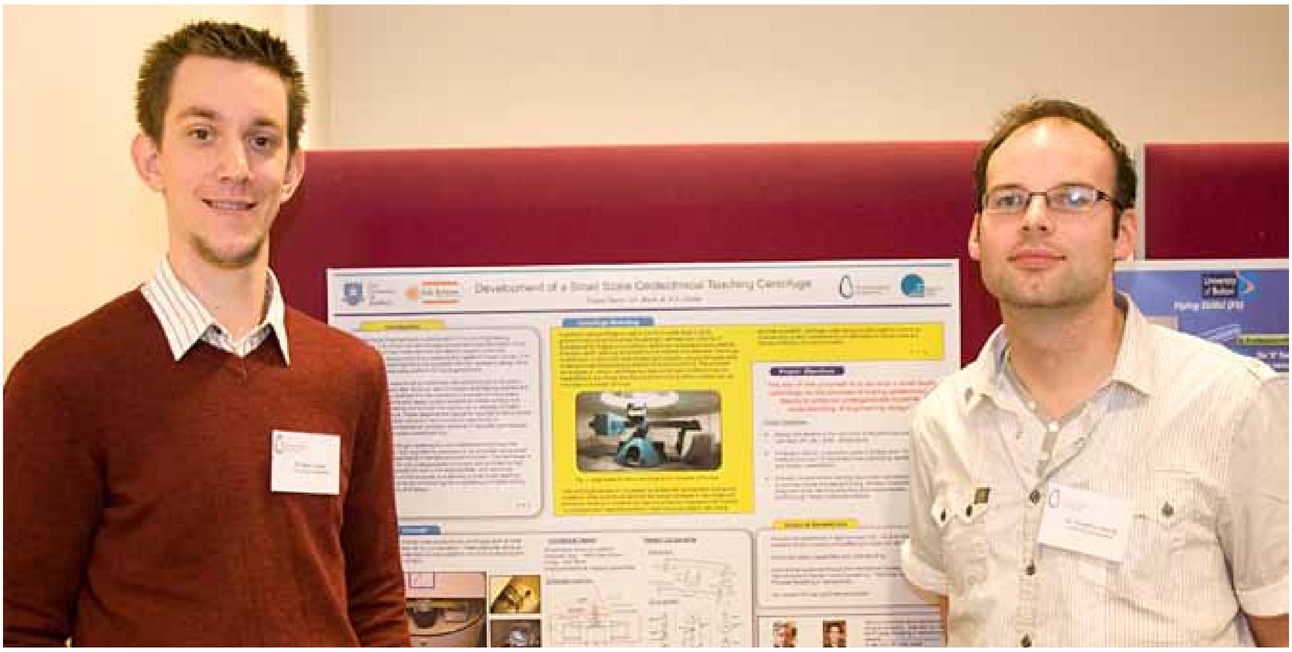
Laboratory-based demonstrations are a valuable learning tool within the engineering curriculum as they provide an opportunity to challenge and reinforce theoretical content taught in lectures. Typically, these demonstrations are limited to element tests used to assess soil behaviour, such as compressibility and strength. While beneficial, these tests fail to provide observations of how actual geotechnical structures perform in practice in routine stability problems such as slopes, retaining structures and foundations. These real life design problems are taught via analytical design calculation methods for a given set of input soil parameters. Although this delivery style may be sufficient as a diagnostic assessment to check that students have basic comprehension of the key design principles, it fails to provide a holistic learning experience. Kolb described a learning cycle often referred to as the *theory of experiential learning*[1], which emphasises the important roles of "observation and reflection" and "active experimentation". This complements Bloom's *taxonomy of learning*[2] which evaluates the student's level of understanding in the learning process, starting with the lowest level (knowledge) and building to the highest (evaluation). For this purpose, physical models are widely adopted in engineering research, practice and education; however, in geotechnical engineering it is exceedingly difficult to demonstrate designs for real world applications (e.g. slope stability) as the full-scale stresses of self-weight cannot be reproduced in small bench-scale models. The key limitation is that the stress-dependent behaviour of soil is not properly accounted for in a 1g environment, thereby making it difficult for quantitative interpretations of the experimental data to be made. While reduced-scale physical models at 1g can provide a basic overview of these problems, models tested at elevated accelerations can demonstrate the subtleties of soil behaviour, produce realistic failure mechanisms and provide simple data for post-test analysis.

Realistic self-weight-induced stresses in a small-scale model can be achieved in the high gravitational acceleration field produced by a centrifuge and thus the stress and strain distributions in the model will be similar to that of a field situation. The geotechnical engineering centrifuge has become an important tool in research activities in many universities and has led to significant breakthroughs in geotechnical engineering understanding in pile foundation, tunnelling and offshore foundation engineering. Whilst most researchers and educators are aware of the teaching potential of centrifuge technology for demonstrating geotechnical design problems within the undergraduate curriculum, the cost of servicing this teaching tends to be prohibitive, as many research centrifuge platforms are large in diameter.

Since the mid-1970s, centrifuge modelling has been used in geotechnical engineering education to illustrate concepts of slope stability, retaining walls, foundations,

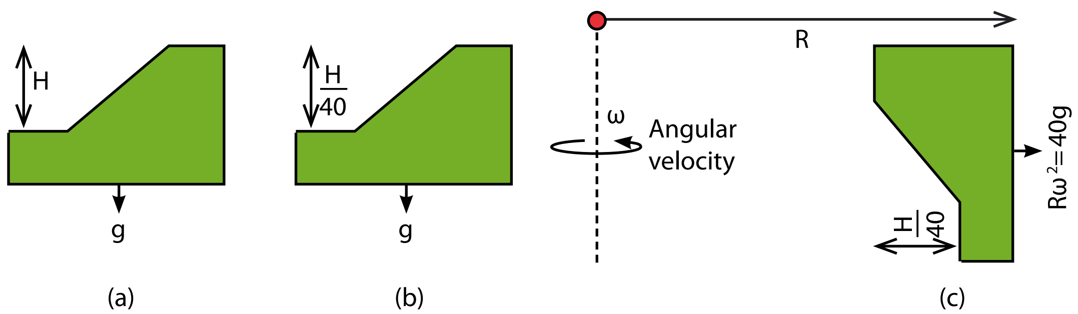
1 Kolb, D. A. (1984) *Experiential learning: experience as the source of learning and development*, Englewood Cliffs, N.J., Prentice-Hall.

2 Bloom, B. S., Englehart, M. D., Furst, E. J., Hill, W. H. and Krathwohl, D. (1956) *Taxonomy of educational objectives: the classification of educational goals. Handbook I: cognitive domain*, David McKay, New York.



tunnel stability and lateral earth pressure theory. However, many of these small-scale centrifuge developments have been undertaken in isolation and established in-house, with no unified approach within the geotechnical community for developing the required technology for teaching purposes.

The University of Sheffield has recently purchased a large 4m diameter centrifuge to establish a leading centrifuge research centre. This brought to the fore the specific objectives of this project which were the development of a small-scale, cost-effective geotechnical centrifuge for the purpose of providing advanced under/postgraduate understanding of key geotechnical theory and design, plus supporting instructional material for routine experimental testing procedures and practical design examples to promote problem-based learning, reflective practices and learner autonomy, with specific support for a new level 7 MEng module, *Advanced* Geotechnics, due to commence in September 2012. This module seeks to enhance students' understanding of geotechnical design through enquiry and problem-based learning to promote critical/lateral thinking and reflective practice. This will be achieved through the integration of advanced geotechnical theory relating to constitutive models to describe soil behaviour, small-scale physical model centrifuge tests, self-learning laboratories and complementary analytical and numerical analysis methods.



$$N_s = \frac{c_u}{\rho H} = \frac{c_u}{\gamma g H} \quad [1]$$

$$N_s = \frac{c_u}{\rho(40g)\frac{H}{40}} \quad [2]$$

Figure 1. (a) Prototype clay slope, (b) model clay slope and (c) model slope in the centrifuge.

An additional core objective was to promote wider use within other higher education institutions (HEIs). This has been achieved by ensuring that the centrifuge is highly cost-effective, built from standard off-the-shelf parts and features supporting documentation in the form of a "*how-to*" guide detailing the centrifuge design, engineering drawings and the manufacture and installation processes for technology transfer. It should be noted that one of the major difficulties encountered was in sourcing off-the-shelf components which were compatible with one another and could be seamlessly integrated into the design of the centrifuge platform. Furthermore, safety was a major concern and thus considerable effort was expended in conducting rigorous structural integrity calculations and checks on all components operating in the high gravity environment.

The project was delivered in the Department of Civil and Structural Engineering. A small-scale state-of-the-art beam centrifuge 1.1m in diameter has been developed which is capable of rotating a payload up to 20kg at 100 gravities (100g), referred to as UOS C2GT/1.1. The maximum sample size that can be tested is 160mm (L) x 100mm (H) x 80mm (W), which relates to full-scale or "prototype" dimensions of 16m x 10m x 8m at 100g. This is sufficient to test a diverse range of reduced-scale engineering structures (such as failure mechanisms in slopes, retaining walls and foundations), while providing stress conditions that realistically duplicate prototype behaviour. The centrifuge is equipped with four 240V 10A power slip rings, dual port 10bar hydraulic rotating fluid union (enabling the delivery of air and water in-flight), digital image capture, load/displacement measurement, signal acquisition, an on-board PC and real-time wireless data communication/transfer. Images are captured through the viewing window in the payload which enables observations of displacement and failure mechanisms.

The delivery plan for the *Advanced Geotechnics* module will incorporate the relevant underlying theory of soil mechanics and design elements. Physical laboratory experiments will be undertaken to evaluate soil properties (such as strength) which will be used to generate predictions of expected design behaviour. Centrifuge model tests on slope stability and shallow foundation problems will consider a range of design geometries (for example, slope angle or foundation width respectively). This will enable comparative analysis between laboratory predictions and real tests and will also generate a suitable database for complementary analytical and numerical validation. To demonstrate the delivery of the module, an example of the student

Table 1. Bloom's taxonomy of learning and its relationship to module content

Level	Tasks addressing different levels of cognitive learning of Bloom's taxonomy
Knowledge	1. Recall analytical methods/theory to analyse stability problems
	2. Recall soil properties needed to inform development of self-directed laboratory
Comprehension	3. Predict centrifuge model performance using relevant theory
	4. Describe centrifuge modelling principles in a technical paper
	5. Engage and discuss original literature (journal papers) via seminar sessions
Application	6. Conduct sample preparation, test set-up and complete centrifuge tests
	7. Grasp the concept of increased g-level; predict g-level at failure for slope
Analysis	8. Correlate experimental observations to validate analysis/numerical methods
	9. Analyse the performance of the problem against design methods
	10. Eliminate erroneous data from data sets; carryout statistical analysis and compare data
Synthesis	11. Compare/contrast expected and actual results and synthesise findings
	12. Evaluate the hypothesis and discuss the outcomes of lab tests
Evaluation	13. Centrifuge data interpretation and reflection
	14. Parametric considerations and recommendations on design theory
	15. Evaluate the success of the research project as a reflection exercise
	16. Peer and self-assessment of performance

learning cycle in relation to a slope stability problem is documented below.

Slope stability design: theory and principal of centrifuge modelling

Consider the case of a saturated clay slope of height H having a slope angle α as shown in Figure 1a. The stability of the slope is dependent on the un-drained shear strength of the soil, c_u, the slope height, H, and the unit weight g = rg and can be related to a dimensionless group referred to as the stability coefficient N_s (after Taylor, 1937). At failure, where the factor of safety is 1, the stability number N_s is given by Equation 1. Reduced-scale physical models for laboratory testing relate to prototype conditions by a linear scale factor, n. If the slope were at a scale n = 40 and tested at 1g (Figure 1b), it would be necessary to produce a model material having c_u / g = 1/40. This is virtually impossible to achieve; however, similitude can be provided by testing the model slope in a centrifuge at n times the earth's gravitational field (Figure 1c), such that the slope stability number can be written as Equation 2. Equations 1 and 2 produce the same stability number; hence it is evident that the model slope in a centrifuge will behave similarly to that in the field.

Slope stability design: experimental methods

The slope stability experiment is probably the most appealing among all centrifuge experiments because students can visually confirm the development of a failure surface. Students will prepare samples for testing by consolidating kaolin slurry, prepared at 1.5 times the liquid limit, to a known vertical effective stress to produce samples of uniform soil strength. A prefabricated former will be used to cut the consolidated block sample of clay to the desired slope geometry. Students will work in groups to conduct a series of tests considering various soil strengths and slope angles to provide multiple data sets for follow-up analysis. The payload bucket containing the model slope will be placed into the centrifuge, ensuring that all required safety protocol is strictly adhered to prior to starting the system. Full details of the centrifuge operational safety features are described in the accompanying "*how-to*" guide. The speed of centrifuge rotation is slowly ramped up to provide increasing gravitational acceleration until failure occurs. A miniature camera fixed to the payload swing bucket is used to capture images of the progressive slope movement and failure mechanism where a distinctive slip plane is formed. The recorded images will be used to assess the slope displacement and failure characteristics using image-tracking methods developed for geotechnical applications (GeoPIV). As part of the experimental activities, students will also be required to conduct complementary self-directed laboratories to evaluate the sample soil properties such as un-drained shear strength, unit weight and moisture content, etc. This data will provide design input parameters for analytical and numerical studies.

Slope stability design: analytical and numerical modelling

The results of soil strength determined by unconfined compressive strength tests in the self-directed laboratory and by *in-situ* vane shear tests will be used in conjunction with relevant theory of stability numbers (Taylor, 1943). In the slope stability laboratory, students will be required to predict the failure g-level for the slope and estimate the un-drained strength of the clay (using inverse relationships of Equations 1 and 2). These performance predictions will be compared with the actual test observations for the range of parameters investigated and collated data sets will be compared against routinely adopted slope stability design charts. Students will be required to interrogate the data set and justify their observations and any discrepancies that exist.

The image data collected is highly valuable as it enables students to visualise and confirm the slope displacement behaviour and failure plane that develops. Numerical modelling will be undertaken to predict the location of the failure surface, centre of rotation and slope factor of safety. The images will be processed using GeoPIV to enable detailed analysis of the slope movement and failure plane. The geometry of the cross-sectional area contained by the failure surface will be compared to numerical and analytical solutions for the slope collapse. Students will be required to assess the "fit" between the predicted and actual results, exploring aspects such as error assessment, sensitivity analysis and statistical methods. The numerical simulations will also extend to a full parametric design evaluation of wider aspects affecting slope behaviour and methods of enhancing slope resistance against collapse.

The centrifuge will have a significant impact on the student learning cycle by providing a deeper understanding and appreciation of routine geotechnical design problems. Furthermore, it will pose challenges and make a positive contribution in terms of developing learning autonomy, critical thinking and reflective practice. Educational pedagogy is embedded at the heart of the module learning practice and it embraces theory such as Kolb's learning cycle and Bloom's taxonomy of learning. Due to the higher level of aptitude expected from final year MEng students, the latter is considered a valid benchmark and educational framework for assessment of this module. Table 1 briefly summarises the taxonomy and its six levels and how these are achieved within the module content.

On completion of the module, it is anticipated that students will demonstrate greater awareness and appreciation of geotechnical design and demonstrate the ability to:

1. Describe the constitutive behaviour of soil and implement appropriate soil models in routine design analysis

2. Develop suitable methodologies to evaluate design parameters through self-developed element test laboratories and *in-situ* sample investigation
3. Develop an appreciation of broader aspects associated with advanced laboratory testing and physical modelling principles such as (i) scaling laws, (ii) dimensionless analysis, (iii) soil model preparation and (iv) instrumentation/electronics
4. Develop suitable experimental methodologies for physical modelling of routine geotechnical problems (slope, retaining wall, foundation) and undertake data measurement/collection
5. Deploy appropriate research methods for analysing data sets, including particle image velocimetry (PIV) for soil displacement analysis
6. Undertake analytical predictions and conduct finite element analysis to calibrate/validate physical model test observations
7. Review and evaluate physical model behaviour with analytical, numerical and classical plasticity methods and discuss the implications for design
8. Develop and deploy scientific research methodologies.

The above expected learning outcomes will be appraised using a variety of assessment methods. The main output will be in the form of an individual scientific technical paper that will present details of the laboratory investigations and results obtained. It should also describe the analytical and numerical evaluation methods employed and discuss/review the correlation of the physical model tests with design theory. The use of a scientific paper is twofold: (i) to instil research methodology within the undergraduate taught programme and (ii) to develop technical writing ability by presenting content in a concise and focused report. Successful completion of this piece of work, which integrates much of the lecture content and practical classes, will require students not only to engage with the directed content, but also to undertake their own background literature review so that they can contextualise the work they have undertaken in the laboratory. They will need to be able to demonstrate technical competence as well as critical and evaluative skills.

Assessment by examination will also be utilised. This will be a blend of discursive and numerical questions to enable students to exhibit their comprehension of design aspects. Successful completion will require students to write lucid prose and demonstrate their understanding of the relevant concepts/equations and ability to critique and evaluate design solutions.

Credit in the module will also be awarded for active contribution and discussion in the reading seminars. Students will also be required to develop an instructional laboratory video on centrifuge testing that will be used as a peer-to-peer learning resource by new students undertaking the module in subsequent years. The physical modelling centrifuge tests, self-directed element test laboratories and learning video will be undertaken in small groups, thus peer and self-review will also form part of these assessments. All other assessments (technical paper, seminar and exam) are individual.

During the first year of use, the project's impact will be assessed through student focus groups, questionnaires and general qualitative assessment of student comprehension by the module leader. While not a measure of student learning, student *satisfaction* plays a significant role in the level to which they engage with the subject matter. This will be determined by comparing historical student feedback regarding their experiences and overall satisfaction in similar design-based modules.

The results of the module evaluation, along with the project materials and "*how-to*" guide, will be published on the project website which has been set up to support the dissemination and sustainability of the project and facilitate exchange of learning resources between participating HEIs (**http://www.geotech.group.shef.ac.uk/teaching/centrifuge**) with a view to developing a support network for the exchange of learning resources and knowledge.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/geotechnical_teaching_centrifuge.pdf**

Designing the Future – engineering education colloquia series

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A synopsis by the editorial team

Abstract

It is imperative to ensure that engineering graduates develop the right knowledge and capabilities to navigate the changing role of the engineer. This will only happen through academia and industry collaborating in a more coherent manner, collectively targeting future challenges. The Designing the Future project aimed to enhance engineering capability in the UK through the proposal of a clear and realistic agenda for the future of engineering education. By bringing together representatives from relevant professional bodies and institutions, employers and engineering disciplines, the project worked to foster a meaningful dialogue and support for action from those with a vested interest in the direction of UK engineering education. The project comprised a series of four colloquia based on a 4S Model for delivering programmes of study (subject, staffing, student perspective and space) and dissemination of guidance in these key areas. Outputs from the series included a road map and key guidance points for engaging with future challenges.

Keywords: engineering education, subject, staff, students, learning spaces

At a time when higher education is undergoing transformational change driven by the funding regime, increasing focus on employers' needs and students' aspirations, increased international competition and the grand challenges of climate change, poverty alleviation, health and wellbeing and resource depletion, there is no better time to test whether our engineering degree programmes, including teaching skills and relevant industrial experience, are fit for purpose. Capability of supply into the industry must be guaranteed; therefore those responsible must work more closely with industry to ensure that graduates have developed an appropriate set of competencies that will promote effective practice from the day they commence. Information relevant to this process must be disseminated to highlight current good practice, focus debate and induce change where needed. It is recognised that, due to the nature of programme development and higher education, available guidance can be vague or simply not transferable. It must therefore be analysed and synthesised to capture findings in the form of practical recommendations that are relevant and transferable across all engineering disciplines. This approach is crucial to ensuring that UK higher education is addressing the requirements of the knowledge economy and remains a world exemplar in a sustainable approach to engineering education. To do so requires regular reflection, consensus and support for action in order to maintain relevance and innovation in programme delivery.

The aim of the Designing the Future project was to enhance the skills and knowledge base of the UK engineering-related workforce through clear articulation of future requirements for engineering education. The objectives set to achieve this aim were to:

- bring together stakeholders relevant to the future of UK engineering higher education for facilitated discussion
- establish a clear rationale for improvement with support for action
- use this support to set achievable goals for the future of UK engineering education, including output dissemination and wider participation
- produce meaningful guidance that will inform future curricula, improve the capability of staff to navigate student and employer needs for an enhanced student learning experience and inspire new perspectives for pedagogy and programme design.

The School of Engineering at the University of Leeds is committed to sustaining world-class engineering programmes through engagement with all engineering stakeholders. Outreach was facilitated through the project partners and The Royal Academy of Engineering to establish an expert base for information management,

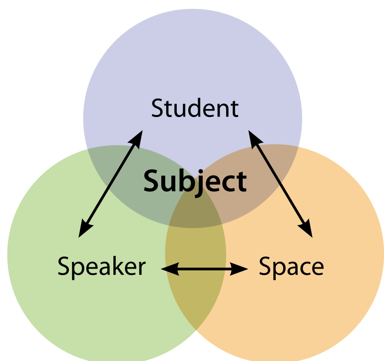


Figure 1. 4S Model

knowledge sharing, group work and plenary discussion. This was expected to provide more benefit than isolated, situational observations and recommendations by instead engaging stakeholders who have the impact and influence to sponsor the recommended action.

The aims and objectives were met via a validated position paper that informed a series of four colloquia hosted by The Royal Academy of Engineering (16 March 2011), the Higher Education Academy Engineering Subject Centre (8 June 2011), JCB Academy (12 October 2011) and Coventry University (20 December 2011). A review of relevant publications was conducted in line with the key themes proposed by the 4S Model (Figure 1). It was the intention of the position paper to highlight the current perspectives on best practice and the issues surrounding UK engineering programmes, verified by the project partners, and from this paper propose a position from which to address them in a series of workshops.

The position paper identified the key issues related to each of the areas impacting on the delivery of effective programmes: the subject, the speaker or engineering academics, the student and the space. These issues formed the basis for the four separate colloquia:

Colloquium 1: The Subject of Engineering

- How can engineering curricula remain fit-for-future?
- Are university processes sufficiently flexible to respond to short-term changes in industry demands? Should they be?
- Does the UK-SPEC inhibit the development of technically capable graduates?
- The level of compliance with the QAA benchmark statement
- What is required to ensure the development of appropriate engineering attributes?
- How should the pre-graduation experience be improved?

Colloquium 2: Staffing for Improving Engineering Education

- The need for an expansion of the Professional Standards Framework into competencies covering all forms of academic staff
- Addressing potential gaps in the current framework in terms of experience requirements
- Recruiting and retention-related issues – research profile requirements
- The need for a continuing professional development tool to aid career development

Colloquium 3: Synthesising the Student-Employer Perspective

- Helping students consider how their programme of study will impact employability
- The role of the engineer in society
- Post-graduate education and life-long learning
- The student experience
- Incorporation of industry practice in education/ practitioners in teaching
- Hard-to-fill vacancies and skill shortages
- Engaging with SMEs
- Ensuring that the best engineering graduates enter the profession
- Attractiveness of engineering as a career – communicating pay and employability
- Attractiveness of graduates to industry – employability skills and experience
- Better communication of labour market requirements
- Addressing the diversity/gender imbalance

Colloquium 4: Engineering Space

- Consideration of the learning environment as part of the building, campus and community
- Effective communication pathways between estates and academics
- Evidence-based guidance, support models and metrics.

The issues were then translated into workshop format as follows:

Colloquium 1

- Presentations:
  - The Subject of Engineering
  - Engineering Knowledge
  - Engineering Knowledge
  - Engineering Attributes
  - Pre-graduation Experience
  - Engineering Education, UK-SPEC Requirements
- Discussions:

- Engineering from now to 2020 – a Road Map to the Future
- The Evolution of the UK-SPEC

Colloquium 2

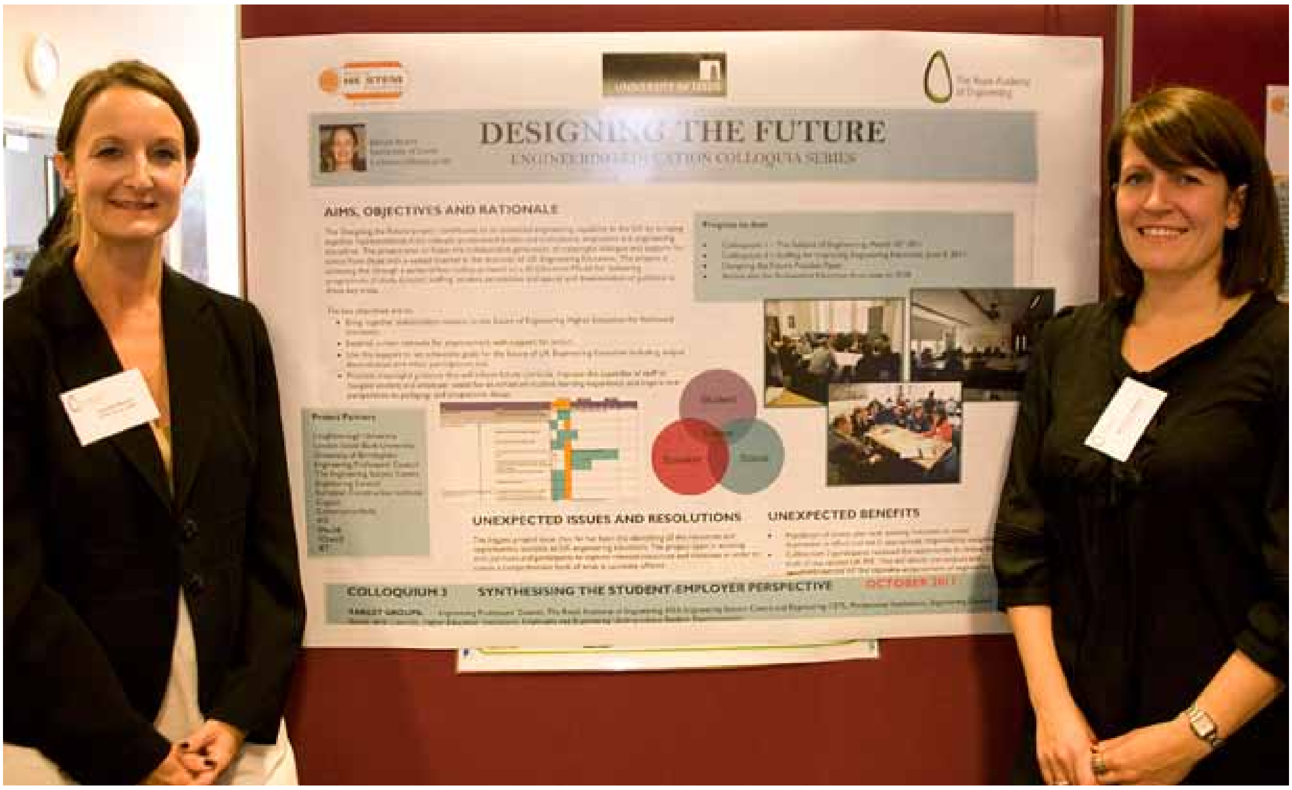
- Presentations:
  - The PSF Review
  - The Roles and Requirements of Academics in Engineering
  - Professional Development
  - Teaching Skills Needs
- Discussions:
  - Building on the PSF Review
  - Career Development Tools for Academics in Engineering

Colloquium 3

- Presentations:
  - Helping Students Transition and Take Responsibility for Learning
  - Transitioning and Incorporating Practice into Teaching
  - Lifelong Learning
  - Understanding the Student Perspectives
  - Employer Perspective – Translating Learning Outcomes into Competencies
- Discussions:
  - Bringing Outside-In
  - Bringing Inside-Out

Colloquium 4

- Presentations:
  - Engineering Education and Teaching Spaces
  - Communicating Requirements to Estates
  - Lessons Learned from Liverpool
  - Virtual Engineering Education
- Discussions:
  - Matching Mode and Environment
  - Best Practice
- Tour:
  - ACT UK Simulation Facility



The key messages and outputs from each colloquium are summarised in the following.

Colloquium 1

Key message: Good practice in isolated clusters, the need for better stakeholder engagement, the importance of different staffing models and flexible, experience related and creative development.

Participants developed a road map to 2020 for future engineering education requirements, including experience, employer and employee needs with reference to programme learning outcomes, the Engineering Council's UK-SPEC and accreditation requirements. The Engineering Professors' Council will take ownership of the actions and the Engineering Council will use the project's feedback to inform their 2013 review of the UK-SPEC.

Colloquium 2

Key message: Communicating the need for different engineering academic job profiles that recognise the importance of teaching and industrial experience to engineering education and addressing tensions with recruitment based on research profile.

Participants were able to review the proposed revision of the UK Professional Standards Framework (UK PSF). Discussion focused on the adequacy of the expansion, the ability of the PSF to address gaps in terms of experience requirements, recruiting, retention and research profile issues and requirements and the need for a continuing professional development tool for engineering academics. Participants identified the need for additional assistance from the engineering academic perspective in balancing recruiting and development tensions surrounding research-led and industrial experience requirements, including relevant industry awareness and getting reality into the classroom. Engineering-specific supplements should be considered. This is also important when considering the future implications of programme Key Information Sets.

Colloquium 3

Key message: Increased exposure to opportunities through information provision and industry involvement. Decide – Plan – Compete.

The event was based on developing guidance to help students to decide on engineering as an option that they wish to pursue, plan to acquire the appropriate skills and experience during their education and compete successfully for opportunities in industry. Following this model, participants identified support requirements for helping student transition into industry and engagement with the employability agenda by bringing outside perspectives into education and promoting the student perspective in an outward facing manner.

Colloquium 4

Key message: Standing firm and deciding when and when not to compromise learning environment objectives in a value engineering situation.

The discussion centred on identifying elements from the spectrum of learning spaces for the effective generation of engineering competencies. This ranged from the physical to the virtual: traditional lecture theatres to creativity labs and simulation. It was proposed that learning space design workshops should be used to create a model of the ideal learning space using metaphors and the identification of actual examples to inform new design. It is important to set the minimum requirements clearly in terms of layout as well as capacity and communicate the student experience as the paramount objective. Participants felt that competencies were rarely targeted individually and students were more engaged by the use of a variety of modes and spaces. Consensus was that there was a 'place for everything'. Highlighted in discussion was the need to consider the level of competency, the point in the programme, the timing of the use of spaces and (most importantly) that, unlike some other disciplines, engineering education cannot be achieved in one space. Participants identified various exemplars, including Mechanical Engineering at the University of Strathclyde, Engineering at the University of Coventry, the Constructionarium and the ACT UK Simulation Centre.

In terms of evaluation, the project objectives of discussion, support and dissemination were achieved. The colloquia served as the first point of impact and dissemination with participants from a wide range of programmes and institutions across the UK. Colloquia success was attributed to good attendance and a high level of debate and willingness to learn and share knowledge and experience. Anecdotal feedback received by the project team was extremely positive.

From this initial feedback it was determined that the approach taken was appropriate. The objectives related to goal setting and guidance generation were also achieved and their impact will be monitored by the project partners over the lifespan of the road map.

The Designing the Future project was approached from a holistic programme perspective and synthesised its findings through an employer, educator and student lens in order to identify practical guidance that is timely and transferable across all engineering subjects. The project has initiated a collaborative approach to assisting UK engineering education in addressing the requirements of the 21st century in terms of attraction and employability and to ensuring that it remains a world exemplar in a sustainable approach to engineering education.

In terms of further development, the project will be sustained through partner organisation support and dissemination and with future schemes looking at:

- Gaining ownership for road map actions (Project Leader and Project Partners)
- Collation of identified good practice for staffing models and learning environments
- Continued efforts to bring together stakeholders for discussion and knowledge sharing, particularly industry bodies and engineering academics.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/designing_the_future.pdf**

Model for engaging women within BME populations into HE engineering programmes in East Lancashire

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A synopsis by the editorial team

Abstract

The aim of this project was to encourage and support women from the BME population in East Lancashire to undertake higher education programmes in engineering disciplines and be aware of the career opportunities which may be open to them within this sector. In Lancashire there are currently skills gaps and shortages within the engineering profession, with many companies reporting hard-to-fill vacancies. Whilst there are many BME females undertaking education within the region there are very few who are studying engineering courses and going into engineering-related careers. The main achievements were the development of an *Introduction to Engineering* module targeted at this group, the development of a targeted marketing campaign and resources and the establishment of a mentoring system for this group of students with local engineering companies. We reviewed our learning environment/teaching practices and identified best practice and gender inclusion tools and provided training to our academic and admissions staff to ensure that they have an understanding of cultural awareness and the influences which are barriers to this group engaging in engineering subjects.

Keywords: outreach, widening participation, women in STEM, careers advice

The Blackburn College approach to widening participation has developed as part of its historic commitment to providing education and training in the context of the local environment and culture. The college aims to recruit students from hard-to-reach groupings (particularly those already in work and those seeking work in particular occupations where representation has been identified as an issue) and provide a high quality educational experience for these students. The majority of the college's higher education (HE) students are local, the first member of their family to engage in HE and mainly from socio-economic groups 4 and 5, including Asian Heritage females for whom the option of leaving home to study is very restricted.

Women in the UK currently represent 8.7% of the engineering workforce, and 76% of women educated to degree level in science, engineering and technology (SET) do not go into SET careers. This figure is much lower when considering females from BME backgrounds. Consequently, due to the low number of females applying for and studying engineering programmes within the college and our high BME population, this project was seen as a way of achieving our objective with respect to reaching under-represented students.

The college is located in the Borough of Blackburn with Darwen, which has an estimated population of 141,000. A gender split of 49% male and 51% female is similar to the college's overall gender profile. The borough is ranked 17th of 354 districts in England in terms of the percentage of people categorised as deprived and has a minority ethnic population which represents around 23% of the total population. Of these, the majority are Muslim, either from Pakistan or India – the third largest such proportion in Britain.

The aim of the project was to encourage and support women from the BME population in East Lancashire to undertake HE programmes in engineering disciplines and become aware of the career opportunities which may be open to them within this sector. It was hoped that the project would create a sustainable model for engaging with and enrolling these students. The project aimed to develop an innovative outreach programme as well as making long-term changes to the teaching practices and learning environment within the engineering department, both of which could currently be perceived as barriers to encouraging female students from the BME population.

Within the local area, many of our local engineering companies are experiencing skills gaps and finding recruitment difficult, due to what is referred to as the "Silver Tsunami" (large numbers of the workforce due to retire within the next twenty years). We firmly believed that if we could encourage females from BME backgrounds into engineering they could provide the workforce required to meet these skills gaps as well as improving their own career prospects.

Our initial approach was to look at the student journey from the initial engagement with the college through to the enrolled student, the type of support they would obtain, placement opportunities and the curriculum. Having looked at these various stages and processes, we were able to identify aspects that we could influence and change that would make a difference to the support and engagement of this group.

Admissions and recruitment

The first area we considered was the admissions and recruitment process. We found that, in some cases, when a BME female approached the college there was an assumption that she would be interested in either a childcare or business-related programme; thus engineering options were not always discussed. It was agreed that the admissions team, school liaison team, marketing team and department staff would benefit from some training in diversity issues relating to STEM subjects. Consequently, the college booked 19 staff onto a one-day workshop for gender and equality training. The aims of the course were to:

- Raise awareness of gender-based attitudes and knowledge amongst staff
- Raise awareness of the benefits of, and the business case for, a positive approach to gender equality in SET
- Improve recruitment, progression and retention of women in STEM
- Raise awareness of the factors influencing access to HE in SET subject areas
- Identify actions that SET employees in higher education institutions (HEIs) can take in order to apply learning from the training
- Produce more inclusive publicity and marketing materials
- Develop the academic research base by ensuring that female talent is not lost
- Improve teaching and learning and ensure inclusivity.

The workshop was excellent. The staff who attended learned a lot and all of them made an action plan at the end of the workshop outlining how they were going to change their working practices going forward. The main benefits of the workshop for the college and the support and engagement of the under-represented group have been:

- The workshop helped to inform the development of new marketing materials aimed at this group
- Admissions staff are now more confident in suggesting engineering programmes to BME females
- The teaching staff have become more aware of the cultural issues surrounding this group and how they can change their teaching practices and environment – as a result of this workshop a mentoring system was established where all females on the programmes are now "buddied" with a student in the year above

- The schools liaison team and careers guidance team are actively talking to BME females about career opportunities in engineering
- The workshop helped to overcome misconceptions that engineering is a male-only career and facilitated understanding of the huge number of career opportunities available in engineering which staff can now discuss with BME females.

Development of a bespoke marketing campaign and literature

As part of the project, we decided to develop and undertake a marketing strategy aimed specifically at this group, including bespoke publicity materials aimed at the learner and the parents of the learners, highlighting not only the learning opportunities, but also career options, including case studies from the local area.

The first aspect of this part of the project was to undertake a review of all of our current and previous marketing literature for our engineering courses, including brochures, the college website and the prospectus. We felt that our existing marketing literature was predominantly aimed at male students and showed quite traditional roles within engineering and manufacturing. We then considered what we had learned about marketing from the gender and diversity workshop and looked for examples of best practice from around the UK. We also found some good examples from America. We used all of this information to develop various poster campaigns and a leaflet targeting this group. The leaflet extols the virtues of engineering as a good career, highlights the diversity of roles within the engineering sector, includes case studies and salary comparisons and introduces the reader to two female members of our lecturing staff. These leaflets are currently being used by our schools liaison teams who take them into local schools and colleges and hand them out at college open days, employer recruitment days and events where industries are recruiting. We are currently looking for other distribution outlets for them, such as local community events and events run by the STEM Ambassador programme.

The leaflets and posters have been met with very positive reactions from potential students, careers information advice and guidance professionals and parents of potential students. As a result of this project, the college now has a suite of marketing materials which it can use and develop on an ongoing basis to engage with females, BME or otherwise, to encourage them to choose engineering careers.

Review our own learning and teaching environment

Three of the lecturers from the School of Science and Technology undertook a review of the existing curriculum and identified barriers to engaging with this group. They concluded that:

1. The projects are not particularly varied and of interest to female students (for example, they all focus on rockets and cars)
2. Many females who are currently undertaking engineering subjects are specialising in either energy or environmental technologies – these are both areas where the University Centre's current engineering curriculum is lacking.

We have come up with a number of other projects which will be offered as options with effect from September 2012, including designing new energy systems for buildings and carbon accounting and improvements.

The department is currently undertaking a re-write of its entire curriculum to take into account the potential students from both female and female BME backgrounds and a new foundation degree in Energy Management Systems has been developed which we feel will be of interest to this group.

Having undertaken this project, the college now feels that it has a better programme to offer which will be more engaging for this group of students.

Development of an *Introduction to Engineering* module

We believed that to stimulate interest and confidence within this group it would be beneficial to develop a 10-credit module as a "taster". The module specification is:

- *The scope of engineering:* introduction to the various facets of engineering (e.g. aerospace, mechanical, chemical, computer science, electrical and electronic, civil, etc.)
- *New topics impacting on engineering:* low carbon, environmental issues and computerisation
- *Career opportunities within engineering:* locally and nationally
- *Professional ethics and social responsibility*
- *Engineering design and projects*
- *Design problems and alternative designs*
- *Feasibility development and optimisation*
- *Design competition*
- *Guest lecturer from industry:* discussing what it is like to be a female engineer (a female from a BME background).

The module has been written by a combination of lecturing staff, with some help from the Lancashire Lifelong Learning Network regarding future job opportunities and local labour market intelligence and skills shortages. The module has only recently been completed and will be advertised to students commencing September 2012.

Mentoring/placement companies for female BME students

One of the key issues for these students is work experience and finding the right environment for them to undertake a work placement. A number of local companies were identified, some of which the college already has work-based learning links with. A briefing letter was sent to 20 target companies to solicit commitment and advise them what this might be. These letters were followed up by a visit to each company that responded to assess their suitability and working environment. As a result of these visits we now have nine companies who are suitable and willing to offer placements and become mentors for female BME students. Some of these companies are large, although many are local small-to-medium-sized-enterprises. In order to assist these mentor companies prior to allocating them a student, we intend to roll out to them the gender and equality training which we undertook.

In terms of evaluating engagement of learners, the college has seen a small increase in interest in engineering courses from females from BME backgrounds which we believe has been as a direct result of our specifically targeted marketing campaign. To date, we haven't actually enrolled any students, although this is mainly due to the fact that the project's marketing campaign was executed in December and January. Hopefully we will be able to enrol learners to start in September 2012 and, with the further development of these initiatives, we feel confident that the project will make a significant impact on learner numbers from this group for September 2013.

When this project began we set out the following evaluation criteria:

1. Number of companies recruited
2. Sustainable changes in teaching practices within the department
3. The development and take-up of the 10-credit introductory module
4. Changes in the recruitment practices of the University Centre for engineering subjects.

All of these criteria have been met, although (as mentioned above) we are unable to evaluate take-up of the module for a further six months. One of the most significant changes has been the changing of attitudes and understanding of the admissions team, school liaison and lecturing staff as they have become aware of the cultural difficulties and how to overcome and discuss these with potential students.

Key outcomes of the project were:

- Mindset change of college staff in discussing and engaging this under-represented group in engineering careers and education
- Development of bespoke marketing literature
- Development of a "taster" module
- Recruitment of mentor companies
- Training of staff in gender and diversity issues relating to the engineering curriculum
- Review of the teaching and learning environment and the embedding of new practices, projects and curricula aimed at this group of learners
- The college feels confident that once it attracts more learners from this group it will be able to retain and support them better, having gained a greater understanding and changed its practices.

We feel that our approach to this project was successful because we had five stand-alone objectives, all of which contributed to the overall success, but could be worked on independently. In terms of what we would have done differently at the beginning of the project, we committed to undertaking events targeted specifically at this group of learners and spent a lot of time trying to establish links within the community to support these bespoke events. However, it became increasing clear that, rather than organising bespoke events, we should have instead been partnering with other events. We have since decided it would be more cost effective and beneficial if we could utilise other events, for example ladies' groups facilitated by Asian Image, college open days and enterprise days.

Through this project, the college has built a sustainable model to engage and support BME females in engineering subjects. The college will continue its recruitment work and will extend this to encompass all females within the local community. We are currently engaging with the MentorSET initiative to see how we can become part of this and how it complements the output from this project. All of the activities and outputs from this project have been embedded into the college's normal practices and will therefore be sustained for many years.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/engaging_women_within_bme.pdf**

Cognitive apprenticeship meets industrial apprenticeship

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A synopsis by the editorial team

Abstract

On civil engineering courses at Coventry University, the presence of two types of student with relevant work experience has allowed a study of realistic project work to take an interesting perspective. The students are: (1) part-time students in the workforce, who study on day-release, and (2) full-time students who have spent a year-out sandwich placement in industry. Semi-structured group interviews with a total of 52 students have been carried out by four members of academic staff in such a way that no member of staff has interviewed students they are currently supervising. The students felt that, in general, the projects were realistic. They benefited particularly from working in areas (mainly technical) that did not correspond to their work area. They indicated that many aspects of the group working experience were not realistic, mainly because of the management structure in the workplace and the professional standards expected.

Keywords: **realistic projects, part-time students, sandwich placements, professional attributes**

The context of this project is the MEng/BEng in Civil Engineering at Coventry University. About 30% of students in any particular year are part-time students in the workforce. They study on day-release and are taught and assessed together with full-time students. Most have had several years' industry experience. It is clear from their performance on the course, including realistic project work, that these students have already acquired many of the attributes and behaviours of practising engineers, within what has similarities to an industrial apprenticeship.

Another relevant group of students are those at level 6 who have returned from a one-year industrial "sandwich" placement and have experienced different opportunities for developing work-related attributes (typically between 20 and 30% of full-time students).

The course includes several significant group projects in which students work on realistic briefs.

The Royal Academy of Engineering has stressed the need for universities and employers to find more effective ways of ensuring that course content reflects the real requirements of industry and has presented case studies of experience-led engineering degrees. Many researchers have referred to the processes by which engineering students develop the attributes of practising engineers, identifying the distinction between an "engineering student" and a "student engineer" and using the educational concept of "cognitive apprenticeship" in supporting the development of engineering students' use of authentic practices in a way similar to craft apprenticeships. To achieve the same objectives, the civil engineering courses at Coventry University (in common with other engineering courses) include elements of realistic integrated project work in every year.

An interesting perspective on these concepts is provided by particular groups of students at Coventry University: the part-time students in the workforce and those at level 6 who have returned from a one-year sandwich placement. This study is intended to provide insights into the development of professional attributes, the value of realistic project work at university and the experience of students who have already developed professional attributes to some extent. We sought to answer the following specific questions:

- What are part-time and sandwich students' reactions to realistic project work? To what extent do they feel it creates the experience and challenge of a real project, including team-working aspects?
- To what extent have these students already developed the professional attributes that realistic project work, in part, seeks to develop?
- How have they acquired them?
- If they have already developed professional attributes to some extent, do they find value in this type of work?

Our investigation was based on semi-structured group interviews with 42 part-time students and ten who had taken a sandwich placement. This represents well over 50% of the available students. We wanted to have a relatively large sample and for all four researchers to have the opportunity for significant involvement in interviewing.

We chose to interview students in groups for three reasons: to achieve efficiency, to promote discussion and to offset any power issues between staff and students. We felt that students in groups would be less likely to tell interviewers

what they wanted to hear; however, we wanted to retain the structure of an interview, as opposed to the more open but potentially less controlled atmosphere of a focus group. We aimed for a group size of four, but this was not always achieved because of the size of the different cohorts and last-minute changes in availability.

One member of the team coordinated the project. The other three team members were academic staff with a heavy involvement in realistic project work across the years of the course. We wanted those involved in project supervision to hear from the students directly, thus interviewing was shared between the four members of the team. It was possible to distribute the groups so that no member of staff interviewed students who were engaged in project work under their supervision at the time.

Each interviewer carried out a thematic analysis of their interview data. This was followed by a discussion by the four researchers of the emerging themes of most significance. Further thematic analysis of the full data set was then carried out. Because of the imbalance in numbers we did not give emphasis to comparing the views of part-time students with those of sandwich students; however, attention is drawn to some significant differences.

- The students felt that, in general, the projects were realistic. They considered that this realism was achieved through basing projects on a real site, with real data, using a realistic brief and was important to make the project engaging, although several pointed out that, while project work at university can be made realistic, 'it's still not real'
- When asked about aspects of project work they felt were less realistic, many comments were concerned with scale and scope
- Some students felt that there was too much freedom for the assignment to be considered realistic (although others thrive on this because it contrasts with their daily work)
- A topic of interest during the interviews was the extent to which the group/team work experience, in terms of working relationships between group members, was seen as realistic. There may be problems, but isn't that what it's like in the real world? There was some agreement with this view; however, it was pointed out by virtually all of the groups that there was a management structure in the workplace; that the boss could intervene if there was a problem in the team. Interestingly, most admitted that this rarely happened 'because you have to act professionally at work'. Some students described potential sanctions in which a colleague might be reported to the boss, but others indicated that they could sort it out for themselves.
- Is there potential for full-time students to learn from group members with industry experience during group work? Some part-time students recognised this and welcomed it. Part-timers may naturally take a leadership role within a group of less experienced full-timers. This was identified by some as a benefit to themselves, especially as many part-time students do not have a leadership role at work; however, this was not welcomed by all part-timers. Interviewees also recognised the potential disadvantage to full-timers that they might miss out on some of the challenge

of project work by relying too heavily on part-timers to take the lead. Balancing numbers of part-time and full-time students in a group is a possible solution here, although this is a sensitive area for part-time students, mainly because of assessment: 'I like doing group work and I like doing these sorts of projects. I just don't want to be marked as a group'

- An explicit aim of the realistic project work is to develop professional attributes and the most common benefit identified was in technical aspects. Asked how they had developed the professional attributes that they already possessed, part-time and sandwich students felt it was overwhelmingly via work, not education. Examples were teamwork and working under pressure.
- Sandwich students were more likely to feel that professional attributes could be developed via the course or leisure interests, including running university societies. Part-time and sandwich students were very aware of what they saw as a lower level of professional attributes among full-time students in, for example, time management
- Another aspect of real value to some of the students was that the project took them beyond their workplace experience. This often went beyond the technical. Some responses suggested that the project work had increased part-time students' confidence in these new areas. All of the members of one interview group agreed when one part-time student described the experience as 'a bit of a confidence boost'
- Sandwich students were particularly aware of the contrast between ways of working at university and in a professional environment, particularly in terms of communication. They also found that full-time students were not good at accepting criticism.

This study has provided some fascinating and useful insights. A particular strength of the methodology used for this project has been that four investigators, with a strong interest in a particular topic, have been able to contribute without interviewing their own students. Of course, we cannot claim that there is no bias, but there has, at least, been a balance between the four members of the team. A weakness might be that two of the four had limited experience of interviewing at the start, although they have benefited from the project by gaining experience.

We feel that the main points to emerge from this study are:

- University projects that are based on real scenarios and real data are considered by those with good knowledge of the industry to provide a realistic experience
- To make projects practicable in a university setting, some loss of realism in terms of scope and scale may be inevitable. Some part-time students feel that freedom and open-endedness may affect realism, but others thrive on this because it contrasts with their daily work
- Students with industry experience benefit more in terms of technical development than development of professional attributes, which they consider to be gained in the workplace. Sandwich students are more likely to recognise personal development at university
- Professional attributes are significant in this context because they define the difference in the way in which students that have industrial experience contribute to group work compared with those who do not. However, those who have already developed professional attributes do not find project work less valuable
- Problems in working with other group members may reflect the real world, but the circumstances are not realistic. This is because of the management structure present in the workplace and the professional behaviour expected as a matter of course
- Part-time students may develop leadership skills when working with full-time students that they do not develop at work. Some welcome this while others do not. This is a sensitive issue because of the link with assessment.

The study has provided the staff team involved with realistic project work in civil engineering at Coventry with some reassurance and plenty of ideas for future development.

The findings of this work will be combined with a separate study of how full-time students can learn from part-time students. This work is ongoing. We then intend to publish the findings more widely.

At a practical level, project work within the department is being given increased emphasis in a new course design and the findings of this study will be relevant in guiding this development. Various changes will be implemented, at the earliest opportunity, in the projects that are the focus of this study, including more involvement by a "client" figure to support coordination within groups and ensuring that, where full-time and part-time students work together, there are at least two part-time students per group.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/cognitive_apprenticeship.pdf**

Using formative group projects with level 4 students to improve student attendance and promote student cohort cohesion

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A synopsis by the editorial team

Abstract

Formative group projects, utilising enquiry-based learning (EBL), were used to engage level 4 engineering students more with their courses and their peers in an attempt to improve both student attendance and cohort cohesion. The students were organised into groups by the academics and asked to design and construct a beam from plaster of Paris and their own choice of embedded material for reinforcement. The project enabled the students to acquire certain 'effective employee' skills that they would not have been able to attain through a formal lecture. Evaluation of the project demonstrated that the students appreciated both the experience of undertaking a practical student-led project and the importance of developing 'effective employee' skills and working in groups to achieve the project aims. The students also appreciated the opportunity to utilise the knowledge they had gained during the early weeks of their undergraduate programmes. Cohort cohesion improved as students from disparate backgrounds worked together in groups during the project and their interaction continued after the project was completed. Attendance and engagement also showed an improvement on the previous academic year.

Keywords: enquiry-based learning, 'effective employee' skills, improving attendance and retention, group projects

The project was aimed at all level 4 students on the five engineering courses delivered by the Department of Engineering at the University of Wolverhampton. All five are offered in BEng (Hons) and MEng format. These programmes share a common first year in that all of the level 4 modules are identical. This is one of the justifications behind targeting all of the level 4 engineering students. Wolverhampton also has a policy where attendance is not compulsory and all lecture materials have to be made available to students on the virtual learning environment. This may be a contributory factor for lower attendance rates and other means were required to maintain attendance and engagement. In addition to the attendance policy, students undertaking the first year of any degree programme at Wolverhampton are not subject to examinations. However, due to accreditation of the engineering degree programmes with both the Institution of Engineering and Technology (IET) and the Institution of Mechanical Engineers (IMechE), this policy changed for engineering students from the 2010/11 academic year onwards so that examinations are a requirement during the first year.

The aim of the project was to engage level 4 engineering students more with their courses and with their peers in order to improve student attendance and cohort cohesion. This was to be achieved by developing a formative group project that would enhance the experience of participating students with regard to attendance and negating social isolation.

Four activities undertaken by the London Engineering Project (LEP) were reviewed in order to determine the best course of action for this project to successfully address the issues of retention and cohort cohesion. Prendergast and Read investigated the development of a practical tool that could be used to promote best practice during both the development and the enhancement of engineering courses, particularly in relation to the factors that affect their validity. These factors are industry demands, student feedback and the widening participation agenda that was being pursued by the government at that time. The research resulted in the development of a checklist that could be used for inclusive course design and assist academics in the review and development of teaching methods, the learning environment and curriculum content.

Read and Worjcik investigated the use of teamwork at MSc level that incorporated generic and transferable skills such as creativity, innovation, team working, presentation skills and project management, in addition to technical and scientific skills. The project also investigated the incorporation of five specific learning outcomes specified by Wanous: commercial and economic, management techniques, sustainable development, legal framework and health and safety and professional and ethical conduct.

Taking into consideration the level of the students for the proposed project, findings surrounding the incorporation of generic and transferable skills were studied and utilised for this project, especially in the context of the comments from some of the students in this study that they would have liked the sessions on generic skills as early as the second year of their programmes, coupled with a rolling programme of generic support. This is of particular importance, as one of the conclusions drawn from the investigation is that the students saw the benefit of the generic skills and this enabled them to become more engaged in learning. The investigation also considered the widening participation agenda and how under-represented groups could be encouraged to consider engineering.

Read produced a generic model that allowed engineering curricula to adapt to change, especially in the context of the widening participation agenda and being able to attract and retain students from a diversity of backgrounds. The model presented in this research provided a holistic view of engineering throughout a higher education institution (HEI) and demonstrated how a series of interlinked strategies are required to make sure that an interesting and diverse curriculum can be embedded into a HEI without the loss of technical content. The research provided a useful insight into the reasoning behind adapting the curriculum, although the main aim of the current project was how to focus a particular aspect of the curriculum to engage the students, in particular how practical skills, creativity and innovation can be harnessed by an EBL exercise.

The initial idea was to examine the effects of the project on two cohorts. The first cohort would have been comprised of all level 4 students from the 2010/11 academic year, with the project being undertaken for these students as a method of *addressing* issues regarding student attendance and cohort cohesion. This cohort comprised 60 students, of whom 57 were male and three female, with the following ethnic origins: Cypriot (17), Polish (2), British Asian (4), Black British (2), African (11), White British (16), Indian sub-continent (6) and Arabic (2). The second cohort was comprised of all level 4 students from the 2011/12 academic year, with the project being undertaken for these students as a method of *tackling* issues regarding student attendance and cohort cohesion. This cohort comprised 57 students, of whom 55 were male and two female, with the following ethnic origins: Cypriot (11), Polish (1), British Asian (7), Black British (1), African (14), White British (11), Indian sub-continent (6), Arabic (5) and Chinese (1). However, due to issues that delayed the development of the project for the first cohort of students, a decision was taken to concentrate on the effects of the project on the second cohort of students.

The approach taken was to utilise formative group projects as a means to develop a strategy for engaging level 4 engineering students both with their lectures (in terms of attendance) and their peers (in terms of cohort cohesion) that were focused on enquiry-based learning (EBL) and required the students to provide a solution to a problem set by the project leader. To raise the profile of the project, it was hoped that the group project would be undertaken in conjunction with a local engineering employer and although no such employer was identified, this was no impediment to its execution. Using formative group projects meant that there was no summative assessment

involved: the outcomes from the projects would not contribute to the students' grades. However, the students would benefit from undertaking the project in other ways; intended benefits and outcomes from the group project work (in addition to those of retention and cohesion) being that the students would acquire the following 'effective employee' skills: team working, team leading, project planning, directing operations, practical skills, effective decisions in problem solving and effective communication. Other opportunities that formative group projects provide are for students to apply knowledge already gained from their degree programmes, to learn aspects of engineering practice that cannot be taught in a formal lecture, to benefit in terms of personal development and to attain a better understanding of the structural design process and the use of materials within that process. Some guidance and information was provided by academic staff at the start of the group project with regard to specific knowledge that the students required in order to undertake it. After this initial guidance and information was presented, the students were then left to determine the solution to the challenge set by the project.

The challenge set by the formative group project was to produce a scaled-down concrete beam constructed using plaster of Paris and various methods of reinforcement, such as embedding fibre or metal wire in the plaster of Paris. Two constraints were set by the project leader with regard to the beams: maximum bending stress and maximum weight of beam. The students were expected to determine and justify within the constraints the mix ratio of plaster of Paris to reinforcement, the type of reinforcement material and the cross section of the beam. They were also required to make their own wooden shuttering/forming. The beams produced by the teams were to be tested to destruction against a 'control beam' of plain plaster of Paris. The team which built the beam with the best strength-to-weight ratio would win the challenge.

The student groups (of four) were pre-determined by the project leader to ensure a mix of home and overseas students, as well as a mix from disparate backgrounds. The students were then required to agree responsibilities in their own teams and keep minutes of meetings and records of decisions made (i.e. who was responsible for what action).The keeping of minutes and records as a tool for group self-management proved to be only partially successful.

The first iteration was disappointing. The majority of the level 4 students of the 2010/11 cohort failed the examinations in the modules that were delivered and assessed in Semester 1 and needed to undertake re-sits for these units. The first activity was therefore delayed until after Easter 2011, during the period leading up to the re-sit examinations (as a means of addressing the retention/cohesion problem). Out of an expected cohort of 50 students, only 12 participated, mainly because the majority of overseas students had opted to return home before the re-sit period. These 12 students were divided into two groups of six. Despite guidance from the project leader and other staff with regard to the expectations of the challenge, neither of the two groups produced minutes detailing discussions related to the challenge, nor did they construct the required beams for testing. Due to the lack of engagement, there would have been no realistic benchmark against which to set evaluation. It was therefore deemed pointless to issue evaluation sheets for the challenge. Reasons for this failure could be due to the challenge clashing with the re-sit period; the students were focused more on passing their exams rather than attempting a challenge. Initial observations suggest that the use of the activity to address a problem after it has occurred is not very fruitful. It was therefore hoped that the use of the activity at the *start* of an academic year (the second iteration), in order to prevent a problem occurring by engaging students when they are 'fresh', would have a more positive outcome.

For the second iteration, a three-hour slot was timetabled for one morning every week over a period of ten weeks for the level 4 students of the 2011/12 cohort to undertake the group project. The slot was timetabled on a day when the cohort had no official lectures; however, the students were informed of the importance of attending the group project sessions in terms of engineering practice skills, personal development and an understanding of the mechanical design process. The sessions were administered by two academics who provided initial information sessions relating to the group project and subsequently monitored student attendance and workshop activity in conjunction with the workshop technicians. Attendance of the project sessions was monitored as part of the project. In the final week, the groups presented their findings to the two academics who then asked the group members questions to determine whether the workload had been spread equally or whether one or two members were 'carrying' the others. At the end of each presentation the group members were asked to complete an evaluation form to feed back to the academics how they had perceived the project and whether they had benefited from undertaking it.

Evaluation was undertaken using an anonymous written survey issued to the students at the end of the presentations. A formal evaluation sheet was developed for the students to complete to ascertain their views of how they thought the project had worked and what skills they thought they had developed during its course. The students were asked 18 questions in total. Of the 44 who completed the evaluation survey, 19 were international and 25 were domestic. The purpose of the evaluation was to determine whether the students had gained any 'effective employee' skills from undertaking it, as well as ascertaining whether the students benefited from undertaking the project in terms of personal development and whether the experience of the project had encouraged them to engage further with their course learning (resulting in improved assessment results and improved retention). Whether or not there was an improvement in cohort cohesion due to groups being pre-determined by the lecturers was also investigated.

91% either agreed or partly agreed that they were sufficiently prepared to get the most out of the project. Several attributed this to the initial information sessions provided by the academics at the start of the project. Only 4.5% partly disagreed that the preparation was sufficient and attributed this to the fact that the topic covered in the project had not yet been studied on their courses. This hints at a misunderstanding by students of what EBL is essentially about (i.e. investigating the project for themselves with minimal guidance from the academics).

Encouragingly, 64% of the students were prepared to act as mentors for students undertaking a similar project in subsequent years.

In terms of 'effective employee' skills developed through the project:

- 95% of students highlighted team working
- 36% highlighted team leading
- 59% highlighted project planning
- 23% highlighted directing operations
- 34% highlighted health and safety awareness
- 66% highlighted practical hands-on skills
- 52% highlighted effective decisions in problem solving
- 70% highlighted effective communication.

Whilst 20% of the students found the project challenges easy and 23% found them difficult, 52% of the students found the project balanced, neither being too easy or too difficult. Some of those who found the project difficult attributed this to not having undertaken a group project before.

86% of students agreed or partly agreed that the project gave them the opportunity to apply knowledge from their degree programmes. This can be justified, as the students were studying a level 4 materials module at the same time as they were working on the group project. 89% agreed or partly agreed there were opportunities to learn aspects of engineering practice that could not be picked up from a lecture. This result can be related to the 'effective employee' skills enhanced by the project.

95% agreed or partly agreed that the project benefited them in terms of personal development. Of those students who left a comment, the importance of team working was stressed.

95% agreed or partly agreed that the project provided them with a better understanding of the mechanical design process. As the engineering programmes share a common level 4, this can be seen as an important factor in terms of retention and progression at the end of the academic year.

Regarding the rating of the overall learning experience, 41% thought that the experience was excellent and 45% thought it was very good. 11% found the experience satisfactory, whilst 2% (one student) found it poor. Regarding improvements to the project learning experience, 66% either agreed or partly agreed that some improvements could be made, in particular with access to the workshop for making the beams. This was a particular difficulty highlighted by some of the student groups which needs to be taken into consideration for future iterations of the beam project.

Some difficulties experienced by the students during the course of the project were also noted. Many of these concerned the calculations involved in the design of the beam and communication within their groups; however, when asked what they thought was their most significant experience during the project, most of the students stressed the significance of team work. This is borne out at the end of the project when, as a consequence of working together in hand-picked teams, barriers between disparate groups of students appear to have broken down and the cohort of students seems to be more confident in socialising and speaking with each other, both within the environment of a group project or lecture and outside during breaks and after hours. Whether this is as a *result* of the group project is open to interpretation; however, based on the cohorts of previous years, the students in this cohort are more confident *after* the project about approaching, talking to and assisting each other.

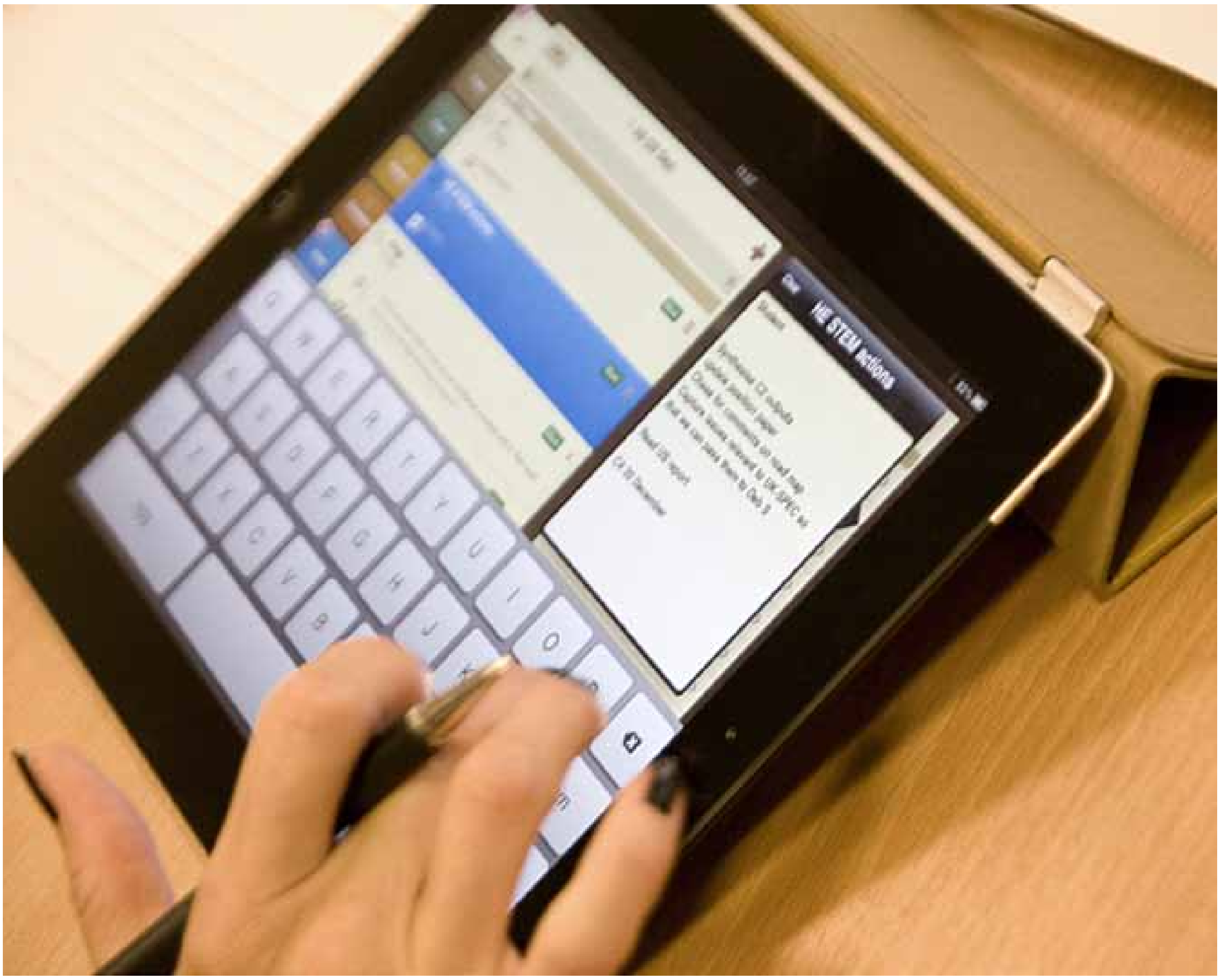
The general overview deduced from the evaluation was that the students found the beam project to be a valuable experience as it provided them with an opportunity to work in groups at an early stage of their time at university. This is of particular importance as the students face summative group project work in the second, third and fourth years of their engineering courses. The project also enabled the students to gain 'effective employee' skills by undertaking the project work with minimal guidance from the academics (whose main role was to maintain an oversight of the process after providing the initial ground rules and information required to undertake the project).

A key point to highlight is the engagement of the students with the project. In the second iteration, only five students out of a cohort of 53 did not engage with the project. Out of these five, two were British Asian, two were white British and one was of Arabic/Persian origin (this student was repeating the academic year due to failure in the previous year). Their attendance did not inhibit the performance of the other students since groups were re-organised during the course of the project, where necessary, to account for their absence.

The use of EBL proved effective as the students were able to demonstrate, through their own initiative, different solutions to the problem set at the start of the project. After the initial information sessions provided by the academics, the student groups delivered beams of various shapes and compositions, some of which conformed to the constraints set by the project, others did not. From an academic viewpoint, the project has highlighted the potential of using EBL within modules as a means of summative assessment and learning. The academics have identified the role of the group project in helping international students to develop confidence through peer support. This is important in the sense that, for many international students, this is their first introduction to independent learning in a university environment where they are expected to take responsibility for their own study. Also from an academic veiwpoint, the students now have a greater appreciation of the mechancial design process. It is hoped that this appreciation will enable them to undertake their engineering studies with both a positive insight into how the design process works and an understanding of how the learning from the modules they study feeds into this process.

Attendance and engagement with the degree programmes appears to have improved as a consequence of the project. More students tend to remain for the full session and are keener to engage with the tutorial material. It is hoped that this will result in improved student retention and improved performance, although at this point there are no official results for modules studied in the first semester of the 2011/12 academic year as the marks have not yet passed through the examination boards. However, performance has improved greatly between the previous and current academic years for the two modules on which the students are examined in the first semester, and indications are that retention for these modules will also greatly improve.

There are some aspects that would be approached differently during future iterations of this project. The main point would be to ensure that the groups were timetabled into the workshop at an earlier stage of the project. One of the main issues to arise was that some groups did not have adequate time (or any time, in one or two cases)



in the workshop to construct and test their beams. An option in future may be to give the students a deadline for detailing their calculations, possibly mid-way through the tenure of the project. This would then allow the latter half of the project run to be used for workshop activities for all groups to have the opportunity to undertake. Due to space constraints, a rota would need to be established that would guarantee equal access to the workshop.

In summary, the aim of the project (to engage first year engineering students more with their courses and their peers in order to improve student attendance and cohort cohesion) seems to have been successful. Attendance has improved during the 2011/12 academic year in comparison with the previous academic year and students from different backgrounds are more readily engaging with each other rather than remaining with their own peer groups. By making use of a formative group project that would enhance the experience of level 4 students, the students have been able to acquire certain 'effective employee' skills that they would not have been able to attain through a formal lecture. The students have also been exposed to working in pre-selected groups, a situation that is likely to occur in the engineering industry where project teams are assembled by a manager. It will be determined at a later stage whether the experience from the project has encouraged the students to engage further with their learning on their courses and resulted in improved assessment results and retention.

It is intended to disseminate the results from this project through the National HE STEM Programme Conference to be held at the University of Birmingham in September 2012. Several regional HEIs will be asked to run the project in future years to gauge the validity of the findings of the initial project run at Wolverhampton.

Further developments include either engaging an employer in the assessment process for future iterations of the project (assuming the same project challenge is used) or asking them to suggest a different project challenge for the students to undertake that encompasses the development of the same set of 'effective employee' skills. The level 4 students who have undertaken this project have already expressed interest in undertaking a similar formative group project during their level 5 studies in the following academic year. The academics will now be seeking a suitable project for these students to undertake. One possible suggestion is to undertake an investigation into the de-lamination of turbine blades due to vibration. A mentoring scheme is also a possibility, a potential strategy being to allocate two mentors to each group to aid the students in their calculations and designs, enabling the academics to take a step back and the project to become more student-centric. The academics will also investigate where and how EBL can be embedded into specific existing modules as summative assessment opportunities. Where identified, the changes towards EBL as summative assessment would have to be approved by the university's quality assurance systems.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/improving_student_attendance.pdf**

Engineering Careers – working with school teachers to improve their knowledge of engineering and enhance their capacity to provide careers advice: a project with National Grid

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A synopsis by the editorial team

Abstract

This project was designed to enhance the capability of teachers to provide relevant and accurate advice about engineering careers in collaboration with National Grid. A newly developed continuing professional development session was delivered to 52 science and technology teachers to enhance their knowledge and confidence with regard to offering advice and guidance to pupils and fellow colleagues. The approach, facilitated with input from higher education institution academics, Science Learning Centre South East staff and National Grid engineers, has been shown to be effective in enhancing teachers' knowledge of careers in engineering and in enabling them to subsequently provide advice and information to students. Reported impact includes enrichment of lesson plans and schemes of work within delegates' schools, including engineering career-specific advice resulting in more effective communication about engineering careers. Teachers now have the confidence to offer specific advice to under-represented groups such as females and pupils from Black and Minority Ethnic communities in order to widen participation within engineering.

Keywords: engineering, careers, lesson, schemes of work, energy, advice, guidance, participation

Students are known to possess limited knowledge of opportunities in and from engineering. Improved information would persuade more of them to consider engineering as a viable option for future employment. Teachers are a particularly influential factor in terms of providing careers information and it is increasingly important that they incorporate careers information into mainstream science, technology, engineering and mathematics (STEM) teaching from key stage 3. It has been shown that CPD would make them more enthusiastic about offering careers information and advice and that it would be easier if there was a single online resource for STEM careers information.

The UK is failing to keep pace with the world demand for engineers and the "traditional" view of engineering and the source of engineers needs to be countered, particularly in terms of attracting under-represented groups such as females and those from Black and Minority Ethnic backgrounds into the field. Careers information, advice and guidance are still reinforcing stereotypes. Students from under-represented groups may be inspired to become engineers but are not able to access the same support in applying to university as students from "traditional" backgrounds; the quality of advice from teachers in schools where there is little experience of students going to university will inevitably be limited.

The approach to this project involved representatives from National Grid, Science Learning Centre South East (SLCSE), the National HE STEM Programme and The Royal Academy of Engineering who formed a planning committee and met to discuss development and design of a one-day continuing professional development (CPD) episode. The project delivered a CPD session to 34 teachers of science/technology which focused on engineering careers at a university-based Science Learning Centre (SLC) and a National Grid facility. The session combined innovative approaches to the teaching of electricity and power generation at key stage 4, including careers-linked content. The aim was to ensure that teachers in schools were better informed of the opportunities and possible qualification pathways for students thinking of entering engineering careers. By highlighting activities undertaken by engineers daily within National Grid operations and wider engineering occupations throughout the UK, the teachers would be better placed to encourage students to make informed choices about degree studies and career aspirations.

The SLCs have long utilised their established expertise and credibility in providing professional development for teachers. Input from the SLCSE was vital in terms of being

the most effective route to achieving the project's aim and providing a mechanism whereby a resultant model could be transferred to other regions through other SLCs. Higher education institution (HEI) academics and National Grid representatives (as the employer partner) also took part in the training days and reinforced this aim. They were able to speak with authority to teachers, many of whom were from a non-engineering background, about engineering and engineering qualifications.

Project delivery was divided into a number of set deliverable activities.

Phase 1

The SLCSE is one of nine regional Centres which are part of the national network of SLCs funded by the Department for Education. The remit of the network is to design, develop and deliver CPD in science education. SLCSE was commissioned to design, develop and pilot a one-day CPD episode for teachers. A key feature of the design was to include inputs from National Grid staff with engineering experience and HEI academics from engineering disciplines. It was important to include approaches to the teaching of power generation as well as information on careers in order to maximise the attractiveness of the course to teachers. This resulted in excellent recruitment to the course. The course (which ran twice) was delivered by SLCSE staff, consultant educators, HEI academics and professional engineers from National Grid. Delivery took place at the University of Southampton and the National Grid control centre at Wokingham in Berkshire. Both venues offered facilities which placed the sessions in "real" engineering contexts.

The project team determined the course content, which included:

- information on careers in engineering, illustrated by contemporary examples exemplifying the range and variety of careers and how to access further information
- the content of modern engineering courses at HEIs, including direct access to examples of current research and employment activities
- an overview of life at university (particularly pertinent to those who are the first in the family or school to study engineering at university)
- best practice in advising students on applying for engineering courses at HEIs (e.g. UCAS application)
- additional opportunities for potential engineering students, including sponsorship
- best practice in encouraging under-represented groups into engineering by targeting each audience segment with an appropriate message set
- advice on working with parents to reassure them of the value to their children of an engineering qualification
- how to access local professional engineers to support careers or other activities in school
- the potential of STEM qualifications as a route to starting a business
- teaching approaches to power generation, including practical demonstrations which exemplified aspects of the operation of National Grid
- a visit to a relevant science facility. This was the High Voltage Laboratory at Southampton and the National Grid control facilities at Wokingham.

Phase 2

Supporting resources were designed and developed to be used as part of the professional development and loaded onto memory sticks to be taken away by participants. This helped to increase the impact and reach of the professional development by dissemination to colleagues in school. The resources included:

- materials for HEI academics and delivery consultants to use to support delivery of the CPD course, including presentation materials and practical activities
- materials to be given to participating teachers/ schools for use in the classroom, including posters, videos for display in schools and case studies. All participants were provided with a copy of the book

Sustainable *Energy without the Hot Air* by David Mackay. A section of high voltage power cable was also given to teachers/advisers to use in careers/science sessions in school.

Phase 3

Piloting of the course took place in December, at a time when teachers were more likely to be released from school. The course was free to attend and teachers were given a £200 bursary which helped with the cost of supply cover and thereby enabled them to attend. Teachers were provided with laptops throughout the day and all resources were on a memory stick. This enabled them to access the resources as they were being used and to personalise and customise them to meet their own needs. The course was evaluated at the end of the day using the SLC network standard evaluation. The SLC impact process was used to help enhance the impact of the CPD. This required teachers to:

- consider their intended learning outcomes before the course and discuss the potential impact with their line manager
- carry out action planning during the course, setting out how they would implement learning back in school or college
- between six weeks and six months after the course, return data on the impact of professional development (to allow for impact to be demonstrated).

Following the delivery of the two episodes, an evaluation meeting between the HE STEM Programme and SLCSE project leads took place and recommended the following revisions:

- Introduce data activities during the morning session in order to enhance the interactive elements of the course
- Include additional input from a HEI representative on enhancing personal statements and applications for engineering courses; teachers are often involved in guiding their students during applications
- Include references to further engineering-related resources.

The revised course was delivered to a further group of 20 teacher delegates. Again, this course was oversubscribed.

Phase 4

Dissemination and roll-out

Following successful piloting, the project is to be disseminated via the following routes:

- SLCSE will run three further instances of the course (one per term) in 2012/13. Further impact data will be gathered, particularly from a longer-term perspective to explore longer-term effects of the professional development
- SLCSE will work with two of its partner Centres to roll the project out across England. In the first instance, the Centres in the East Midlands and Yorkshire and Humber (due to their proximity to National Grid facilities) will be offered the opportunity to deliver the project in their own region. This approach will test the transferability of the project and establish best practice for sharing of the resources. Following successful piloting with these two Centres, the best approach for offering the course to the network will be determined
- The project is to be presented at engineering and STEM-focused seminars/conferences.

The professional development days were designed to train 20 delegates per instance. Recruitment for the events was very good, with both being oversubscribed within several weeks. There were 34 attendees in total at the two initial events and 18 at the extension event. Initial evaluation, using SLCSE standard evaluation processes, was extremely positive, with over 98% of delegates indicating that overall course quality was "good" or "very good", that course outcomes had been fully or at least mostly met, that the course would be useful to their practice, that they had enjoyed it and that they would recommend it to others. Several commented specifically about how pleased they were to meet practising engineers from National Grid.

An assessment of the project-specific and medium-term impacts of the training and resource provision was carried out. A web-based survey was designed and commissioned several weeks after the two CPD events. The aim was to solicit specific information regarding the delegates' backgrounds, use of the resources to date, how the delegates felt their confidence in the subject matter had improved or otherwise and their plans to disseminate the information, both to students and colleagues. 18 of the 34 delegates responded (of which only one-third had any degree of engineering experience), the majority of whom now felt confident in giving advice to colleagues and pupils and finding relevant resources to support this advice. They were also confident in their knowledge of entry requirements for routes into engineering (i.e. vocational apprenticeships, further and higher education) and felt that they were now better equipped to promote engineering careers to under-represented groups (such as females and Black and Minority Ethnic groups).

Evaluation of the resources given to the delegates on leaving the event and use of the knowledge gained within the training was particularly encouraging.

Within a very short time frame of a few weeks, 78% of the respondents had already used the resources to disseminate information to pupils and colleagues. It is clear that the resources and information already and potentially have a great deal of impact when considered against the project aims. Individual pupils and department colleagues have already benefited from the acquired knowledge and future lesson plans and schemes of work at key stages 3 and 4 are being updated to include aspects of the CPD training.

Impact evaluation of the project (and the professional development course in particular) will continue as teacher delegates return their *Impact of professional development* (IPD) forms to SLCSE.

In summary, this project was an innovative approach to professional development relating to careers in engineering in that it brought together practising engineers from industry (National Grid), HEI academics and experienced professional development trainers. Combining this expertise brought an authenticity to the experience and offered teachers the opportunity to access a range of resources about careers. The sessions included visits to "real" facilities which enhanced the experience for those attending. The evaluations showed that teachers valued all aspects of the courses and SLCSE will be observing a sample of teachers to assess longer-term impact.

The approach has proved to be highly successful in bringing professional development to teachers in terms of engineering careers. Part of its success results from careers information being put into the context of teaching resources linked to the operation of National Grid; the combination of innovative resources, including fascinating facts and figures on power generation, appealed to teachers and helped to put the whole area into a relevant context.

The project has been included in the following resources:

- HE STEM Programme *Creative Learning Journeys* video resource
- HE STEM Programme *HESTEMnews*, Spring 2012: **http://www.hestem.ac.uk/sites/default/files/he_stem_news_spring_2012.pdf**
- London and South East region HE STEM programme website: **http://www.southampton.ac.uk/hestem/**
- HE STEM Programme London and South East Regional Spoke: dissemination brochures will be sent to Spoke mailing list addresses and outreach teams across the region
- The project will be taking a lead position in a conference on *Engaging with Engineering*. The audience will include head teachers/department heads, engineering Regional Action Plan projects, regional engineering small-to-medium-sized-enterprises and national engineering companies
- The project will be showcased as a case studies/good practice guide that the Public Engagement and Widening Participation Special Interest Group (PEWP SIG) are producing for the National HE STEM Programme Conference in September 2012. This will also highlight the project and disseminate it further to a national audience.

Going forward, National Grid is keen to support further events and is also exploring the methods used to approach teacher/pupil interaction. SLCSE is using the project to involve further corporate organisations and is also using the model to explore other areas of science careers professional development, including the polymer industry. The Director of the Centre is in discussion with the Network's Director of Programmes regarding the possibility of including the professional development in the SLC Network core programme.

A best practice guide outlining the design, delivery and outcomes of the project is currently being produced by the SLCSE. This will be made available via the HE STEM Programme website.

In order to increase capacity in the future, SLCSE has decided to employ a co-presenter (an external consultant) who has worked closely with the Centre and has experience in delivering a similar programme.

If future events are to be undertaken by this project team, or by teams at other institutions, it is recommended that consideration be given to the following developmental points:

- The inclusion of specific advice concerning HEI admissions (which could include advice on applications to HEIs)
- Those undertaking similar careers advisory activities may well consider it appropriate to include diversity experts such as the UK Resource Centre (UKRC) in the forward design committee
- A *Sharing of best practice in teaching* session could be included, thereby drawing on the pedagogical expertise of practising teachers
- Course delivery staff may consider inviting a previous delegate back to discuss how they have used the approach in the classroom
- The session should include some degree of signposting to resources that teachers can utilise within careers and science lessons. These resources can be used to target specific areas or under-represented groups. Examples include:

- Links to the National STEM Centre (**http://www.nationalstemcentre.org.uk/**). The National STEM Centre in York is collating the largest collection of resources for teachers of STEM subjects in the UK
- The Royal Academy of Engineering education links (**http://www.raeng.org.uk/education/usefullinks.htm**). The site has useful links to educational and careers resources
- Engineer Girl website (**http://www.engineergirl.org/**). A US site dedicated to the advancement of girls into engineering disciplines
- National Grid education website (**http://www.nationalgrideducation.com/**)
- Organisations whose aim it is to shape education and act as an interface between business and education when promoting change. Examples include the Ellen MacArthur Foundation (**http://www.ellenmacarthurfoundation.org/**)
- Funding organisations that support high ability pupils, such as the Engineering Development Trust (**http://www.etrust.org.uk/**), Arkwright Scholarships (**http://www.arkwright.org.uk/**) and Happold Trust (**http://www.happoldtrust.org/**)
- Previous project resources such as case studies and usable facts. The Royal Academy of Engineering London Engineering Project (LEP) specifically targeted widening participation in terms of girls, students with no family history of higher education, Black and Minority Ethnic students and adult learners. The LEP website hosts a wide selection of resources, including case studies and interesting facts that can be used by teachers to engage pupils in discussion (**http://www.thelep.org.uk/home**)

This list is not exhaustive and individual evaluation of each event will guide future development.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/engineering_careers.pdf**

Engineering Students Understanding Mathematics (ESUM) – research rigour and dissemination

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A synopsis by the editorial team

Abstract

The Engineering Students Understanding Mathematics (ESUM) project was a developmental research project aimed at enhancing the quality of mathematics learning of students of materials engineering in terms of improving their engagement and conceptual understanding. The initial phase of the project consisted of an innovation in mathematics teaching-learning which was designed, implemented and studied, with feedback and concomitant modification to practice. Details are reported in the case study for phase one. The second phase of the project, reported here, focused more overtly on the analysis of data in relation to theoretical perspectives. In particular, Activity Theory (AT) was used to make sense of emerging findings. A literature review was undertaken and showed evidence of so-called 'constructivist' methods being introduced to the teaching of mathematics in higher education. Dissemination has taken place both internally within the institution and externally and is still ongoing. It has generated interest and activity beyond the local setting. Findings from the project include students' views on elements of the innovation, improved scores on tests and examinations compared with earlier cohorts and ways in which students' strategic approaches to their studies creates tensions with lecturers' aims in designing the innovatory approach. The gains from the projects can be seen in terms of developing knowledge of the complexities of achieving principles for more conceptual understandings of mathematics within the context and culture in which teaching and learning take place.

Keywords: mathematical understanding, engineering students, innovation in teaching, inquiry-based activity, activity theory, students' strategic approaches

The Mathematics Education Centre (MEC) at Loughborough University (LU) includes a group of developmental researchers who seek to improve the teaching of mathematics university-wide. The group is particularly renowned for its work in mathematics support. This case study reports on the second phase of the Engineering Students Understanding Mathematics (ESUM) project. Full details of the initial phase are reported in the case study for phase one available on: **www.hestem.ac.uk/sites/default/files/esum_1.pdf**

This programme has built upon collaborations between the departments of Mathematics and Materials Engineering at LU over three years. The common goal was mathematical understanding as it relates to engineering. During this time the mathematics curriculum was modified and styles of teaching developed. Materials engineering problems were sought to which mathematics could be related in order to motivate students. The software package GeoGebra – free software which allows both algebraic and graphical representations of a function to be displayed side by side on a screen – was used to provide a means for conceptual visualisation around key mathematical concepts. Associated inquiry-based questions were designed and used in tutorials to motivate students and encourage mathematical engagement. (It is recognised that an inquiry-based approach to learning engages students in collaborative exploratory activity through which they ask their own questions, take up their own lines of inquiry and hence develop a more conceptual understanding of mathematics.)

In ESUM, a decision was taken to cohere these various approaches in an innovative teaching schedule designed to stimulate and challenge students and encourage a deeper engagement with mathematical concepts through participation in focused activity with their peers in which pedagogy was inquiry-based. Inquiry was seen as both a tool and a 'way of being' in practice, designed to draw participants into a working relationship with mathematics within a community of mathematical practice related to becoming an engineer. It is possible to see university mathematics teaching as an established community of practice (CoP) of which, in this particular case, lectures and tutorials, mathematical curricula, university ethos and academic and student cultures each form a part. Briefly, teachers and students together engage with mathematics, seek to fulfil teaching and learning goals, use resources and interact in ways that are in common practice within that community. A community of inquiry transforms a community of practice by encouraging a critical approach both in learning mathematics and in the design and development of teaching. This encourages scrutiny of established practices and the possibility of achieving more effective learning outcomes.

Although aimed particularly at materials engineering students, the project's focus was generic, with the possibility of influencing the design of teaching broadly within LU and beyond. Design of teaching and its implementation were researched with data gathered from all phases of the project and analysis taking different forms at different stages. Students were required to work in groups in tutorials using GeoGebra and assessment was modified to include an inquiry-based group project aimed at enhancing participation and understanding. The second phase of ESUM encompassed a literature review, further analysis, dissemination and the relation of findings to theoretical perspectives.

The ESUM project worked with a cohort of 48 first year (level 4) materials engineering students in the academic year 2010/11 during the first semester of a year-long module of 30 weeks with two lectures and one tutorial each week. The students came (in the main) directly from school and were *in transition* between two important phases of education. Their previous school experiences and their first perceptions and expectations of the new environment, as well as youth culture and strategic goals for their higher education (HE) all contributed to their engagement in learning mathematics.

The main aim was to engage these students in mathematics in a more conceptual way that prepared them for the use of mathematics in problem-solving situations in engineering. The programme involved developmental research: that is, research which actually influences the developmental process as well as charting the development. A programme of teaching and assessment was designed that incorporated 1) the use of inquiry-based questions and tasks, 2) the use of a dynamic algebra-geometry electronic environment (GeoGebra), 3) students' small group activity and 4) an assessed project that brought together elements 1, 2 and 3.

The project team consisted of three academics, experienced in teaching mathematics at various levels and comprising the teaching team, and one research officer, employed specifically to undertake elements of the research. The teaching team variously designed questions and tasks, planned the group project and organised the research. One member was the lecturer in the first semester. Two PhD students contributed to designing questions and tasks. Design and planning were documented, lectures were observed and audio-recorded, students were surveyed twice during the first semester and interviewed during the second semester and the lecturer in the first semester wrote reflective notes after each week of the teaching. Analysis was ongoing during the first semester and involved an informal level of reflective conversations between the lecturer, the researcher and a graduate assistant along with analysis of the two surveys.

In the second phase, reported here, funding was sought for further analysis and to support a deeper (that is, more theory-related) level of analysis. During the second semester, two individual and two focus group interviews were conducted by the researcher and one member of the teaching team and subsequently analysed. Analysis from the second student survey and from these interviews provided information relating to students' experiences of the module. A literature search was conducted to reveal findings in engineering, mathematics and science teaching that related to this programme. A theoretical base was sought that would fit well with ongoing practice and support the analysis of data. There was an expectation that this would be contrasted with theory propounded in the related literature in the HE sector and at school level. In addition, this phase would feed back findings to inform modifications to teaching and assessment practice for the next cohort of students in the first semester of 2011/12, extend dissemination overtly to groups of professionals and researchers and begin to consider the wider applicability of what was being learned, seeking perspectives of colleagues in other branches of engineering education and opportunities to influence practice in the design and implementation of learning and teaching.

The literature review (of mostly recent US papers, with a few from the UK, Australia and Malaysia) was conducted by a post-doctoral fellow in the Engineering Centre for Excellence in Teaching and Learning (engCETL) at LU. The findings provide a snapshot of emerging trends in approaches to mathematics instruction for STEM subjects in HE. Calls for reforms of mathematics instruction have been stressed in a number of studies and responses to these calls have embraced, in general, novel 'constructivist' methods for implementing changes in the learning and teaching of mathematics. A number of trends have been observed and were categorised in six groups:

1. The use of student-centred learning methods
2. Contextualisation of mathematics using real-world examples
3. Bridging the gap in previous mathematical knowledge

4. Encouraging discourse in the classroom and amongst students
5. Enhancement of students' motivation, engagement and self-efficacy
6. Consideration of different learning styles.

Thus, methods for facilitating conceptual understanding include novel pedagogies (e.g. collaborative learning, inquiry/problem/project/discovery-based learning), contextualising with real-world examples and the use of documentary movies for stimulating motivation and self-efficacy beliefs. Mathematical software packages (e.g. GeoGebra, Matlab/Simulink, LabVIEW, Mathematica, Maple and MapleTA, etc.) and online tools (wikis and web-based courses) are increasingly being used to support learning of mathematics. There is evidence of a trend towards developing new approaches to teaching mathematics, motivated by a desire to achieve more conceptual or in-depth understanding of mathematics by students in STEM subjects in HE, of which the ESUM project (with its relevant methods and pedagogies) might be seen to be a part.

The theoretical base that was deemed appropriate was *Activity* Theory (AT). In AT terms, the activity is everything, not just the sum of all the parts. AT is used specifically to address issues that are seen *between* the intentions of the approaches to teaching and use of resources (in the innovation) and students' responses, engagement and performance. The context is central to analysis, but hard to factor in. One purpose of the use of AT is to try to make sense of the relationship *between* the purposes of the innovation and associated findings *and* the aspects of context in which the innovation is embedded. Two additional areas of theory which are important to ongoing work are *documentational* genesis, which deals with the growing awareness of the teacher(s) of the methods and resources being used and their schemes of utilisation, and *constructivism*, a conceptualisation of knowledge and learning from which implications can be seen to arise for approaches to teaching.

Individual interviews and two focus groups (each involving four students) were held and the data analysed by the researchers and two members of the teaching team. Students were asked for their perceptions of the various aspects of the innovation and their learning of mathematics in the module. It appeared that, while they valued many aspects of the innovation, students were motivated largely by a strategic approach to their learning, having very much in mind what was needed in terms of assessment and what they had to achieve in order to pass the course. This led to some apparent contradictions in the evidence discerned. For example, although students appreciated many of the qualities of GeoGebra (especially visual representation and the use of 'sliders'), they questioned its use more globally. It was suggested that GeoGebra does not involve doing mathematics, just plugging numbers into a computer. Several students felt that the time taken up by GeoGebra was seen as cutting short the time available for the lecturer to solve problems or to practice past exam papers. Several said that they did not use GeoGebra outside tutorials, except for the assessed group work. These students claimed that they did no work outside of taught sessions except for the group project and revision for CAA tests. What is shown here is possibly both a reflection on students' past educational experience and the nature of student epistemology. They perceive that they need to do well in the exam and in other forms of assessment in order to pass the module and they focus on this strategically. Understanding functions through visualisation with GeoGebra is not, as they see it, directly usable in the exam, so it is not the kind of understanding they value.

A similar perspective was reflected by their views on inquiry-based questioning. Students were surprised to be asked questions in lectures, expecting instead to just take notes. They recognised that such questions can be useful in terms of highlighting areas in need of clarification, although one said that they would rather be studying past exam papers. Again, a conflict is observed between the teaching intentions and students' aims. Are students being lazy here (too much effort required to engage) or are they focused on taking notes rather than trying to understand? Or is this again their strategic perspective (there is only a certain amount of time and they feel that it would be best spent on things such as past exam papers)? Regarding inquiry-based questions in tutorials (designed to promote engagement and understanding through use of GeoGebra with exploration and discussion), they were unhappy with the format. Having computers was distracting and they did not find exploratory work and discussion with other students with whom they might not otherwise converse to be a good use of their time.

In order to make sense of these apparent dichotomies between student and teaching perspectives, an AT analysis was imposed onto the basic analysis. For this, Engeström's expanded meditational triangle and Leont'ev's three levels of activity were used as tools. The use of these two models allows situation and context to be characterised through juxtaposing key elements of the areas of conflict. Table1 shows the presentation of ESUM findings in relation to Leont'ev's three levels of activity. This helps us to see where differences in culture, perception and attitude lead to tensions and impede progress. From such analyses we gain a clearer knowledge of the issues to inform the design process and influence future teaching. With a new cohort of students, we reflect on what has been learned and how this learning may inform ongoing design and organisation. These questions are still under discussion and relate to the use of the theory of documentational genesis mentioned above. The AT analysis helps us to see how use of resources might be modified to enable the learning that is sought to be realised through modifications to practice. We thus develop a more knowledgeable approach to our use of resources and the experiences that are offered to students. This development of teaching knowledge is what is meant by documentational genesis.

In evaluating this phase of the project, it is important to acknowledge what was reported in the first case study. The following six points present a summary of that evaluation (from analysis of data from the ongoing progress of the module and from quantitative analyses from surveys and assessments). Further details can be found in the case study itself. The findings presented there, together with results from survey analysis and module assessment, suggest that areas of achievement in the project are:

1. Greater participation (mathematical engagement) by students in lectures possibly responding to greater effort (than in previous years) by the lecturer to include students through frequent questioning and inviting students to respond, comment and ask their own questions
2. Higher student attendance in lectures and tutorials than in previous cohorts
3. Pleasing (to the lecturer) response by students to group work in tutorials and to project work. Enhanced engagement in particular was commented on by the graduate student who has helped in tutorials over two years. VERY pleasing participation in design of a poster
4. A good average mark for the projects
5. CAA scores at about the same level as for previous cohorts, despite each CAA test having almost twice the number of questions for the same amount of time

Table 1. Leont'ev's three levels of activity applied to ESUM analysis of focus group data

activity <--> motive, actions <--> goals and operations<--> conditions.

Level	Teaching	Students
1	*Activity* is mathematics teaching-learning, *motivated* by the desire for students to gain a deep conceptual-relational understanding of mathematics. This may be called 'teaching-for-learning'.	For students the *activity* is learning within the teaching environment and with respect to external factors (youth culture, school-based expectations of university etc.) and is (probably) motivated by the desire to get a degree in the most student-effective way possible.
2	*Actions* are design of tasks and inquiry-based questions, with *goals* of student engagement, exploration and getting beyond a superficial and/or instrumental view of mathematics. *Actions* include use of GeoGebra with the goal of providing an alternative environment for representation of functions offering ways of visualising functions and gaining insights into function properties and relationships. *Actions* include forming students into small groups and setting group tasks with the *goals* to provide opportunity for sharing of ideas, learning from each other and articulating mathematical ideas.	For students, *actions* involve taking part in the module: attending lectures and tutorials, using the LEARN* page, using the HELM† books, etc., with *goals* related to student epistemology. So *goals* might include attending lectures and tutorials because this is where you are offered what you need to pass the module, clear views on what ought to be on offer and what you expect from your participation, wanting to know what to do and how to do it, wanting to do the minimum amount of work to succeed, wanting to understand and wanting to pass the year's work.
3	*Operations* include the kinds of interactions used in lectures to get students to engage and respond, the ways in which questions are used, the operation of group work in tutorials and interactions between teachers and students. The conditions include all the factors of the university environment that enable and constrain what is possible – for example, if some tutorials need to be in a computer lab, then they all have to be; lectures in tiered lecture theatres constrain conversations between lecturer and students when tasks are set.	*Operations* include degrees of participation: listening in a lecture, talking with other students about mathematics, reading a HELM book to understand some bit of mathematics, using the LEARN page to access a lecture PowerPoint. The conditions in which this takes place include timetable pressure, fitting in pieces of coursework from different modules around given deadlines, balancing the academic and the social. They also include the organisation of lectures and tutorials and participating within modes of activity which do not fit with your own images of what should be on offer.

*LEARN is the VLE used for all learning-teaching at LU.
† HELM (Helping Engineers Learn Mathematics) is a series of booklets addressing key mathematical concepts related to engineering studies.

6. A considerably higher exam average on the module as a whole and on individual questions relating to learning in the first semester.

The analysis conducted in the second phase (and discussed above) was largely of qualitative data from project reports and interviews held in the second half of the module after the intervention. Students were reflecting on their past experience and thinking towards the final examination. It is interesting that overall scores in this examination were much higher than those of previous cohorts.

A major part of the innovation was the change to assessment reflected in the project (a reduction of 20% in CAA tests in order to award 20% to the project report and poster). Students took the project seriously because it affected their assessment and their responses showed that they gained in aspects commensurate with the principles behind the project. This fits with educational wisdom, which suggests that changes to teaching must be reflected in assessment if they are to be successful. However, the qualitative analysis of the interview data revealed the dichotomy expressed above. This challenges a re-think of perspectives at the design and implementation stages of the project. While there was evidence of degrees of engagement and understanding as reflected in the projects, posters and exam results, it was clear that students had not been persuaded of the value of seeking inquiry-based engagement or an appreciation of the conceptual nature of understanding. It was also recognised that better (more objective) ways of judging conceptual understanding and its development were required. To this end, work is being conducted with colleagues at the National University of Ireland, Maynooth and CASTeL, St Patrick's College, Drumcondra to design and test an instrument to assess an increase in conceptual understanding (perceptions of which are being challenged).

In summary, the innovation has shown considerable promise in engaging students and suggesting alternatives to an instrumental view of learning mathematics. The principles behind the innovation have been shown to be sound. It is the detail that needs attention, particularly with respect to context and culture.The intrinsic rewards of deep conceptual understanding and the value this brings to studies remain largely outside students' thinking and culture.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/esum_2.pdf**

Development of engineering project management simulations in a virtual world to enhance students' engineering project management and employability skills

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A synopsis by the editorial team

Abstract

The purpose of this project was to use the virtual world (VW) of Second Life to support students in the development of deeper understanding and application of engineering project management (EPM) whilst offering flexibility and continuity of remote access to interactive materials. This was achieved by using previously developed and evaluated scenarios* in Second Life (for example, a YouTube video – **http://www.youtube.com/watch?v=ZK5_dHqPTdQ**) and redeveloping them for EPM and employability skills. Evaluations by the London Engineering Project (LEP) highlighted the benefits of remote access interactive teaching materials for issues faced by engineering departments in curriculum delivery to a diverse student base (WP).

Keywords: **project management, Second Life, simulations**

* Scenario is a term used to represent the idea of a case, problem or challenge that a student is required to manage as a component of the learning process.

Project management (PM) is a very experiential subject. It is relatively easy to teach students the tools and techniques associated with PM but to actually give students practical experience in using these tools and techniques is more complex. Traditionally this has tended to be done through the use of computer/paper-based simulations, often designed more for internal company training as opposed to an undergraduate situation. PM is challenging to deliver using conventional delivery modes. Previous methods used to address such issues include simulations (paper and computer-based), but these have been found to be time consuming, restrictive for students and lacking flexibility in delivery. Several publications generated through the London Engineering Project (LEP) have highlighted the need for flexible, accessible, interactive teaching materials as a means of engaging learners. Considering this and the positive research results in the area of Activity Led Learning (ALL) conducted by Coventry University, the evidence for identifying further innovative ways to deliver the engineering curriculum generally (and PM in particular) is overwhelming. Second Life has been shown to be an innovative, pedagogically robust teaching tool and has been successfully used to develop scenarios to demonstrate real life situations otherwise unavailable to students (such as healthcare and disaster management). One of the major drawbacks is the time required to generate and build each individual scenario. A key benefit (in cost, time and experience) of this project is that it drew on developed scenarios and trained members of staff to adapt complex scenarios to fulfil PM and employability learning outcomes.

The level 3 PM module based in the Faculty of Engineering at Coventry University is quite challenging. Aside from the problems of teaching PM raised above, the module is taught to over 400 predominantly international students and has now been developed into a distance learning module that students study in their home country prior to beginning their studies at Coventry. In addition to this, Coventry University's Faculty of Engineering is becoming internationally known for its movement towards Activity Led Learning (ALL) which, whilst similar to problem-based (PBL), is far more focused on the needs of industry than has traditionally been the case with PBL. Many of the undergraduate courses have ALL at the heart of their level 4 and 5 delivery, as do many education innovations within the Faculty.

Activity 1

The first thing that we did was build a dedicated area in Second Life that we would be able to use to deliver our simulation. As Coventry University is spending in the region of £60 million to build a new engineering building dedicated to ALL delivery, it was decided to construct this building in Second Life and develop an ALL classroom in which to deliver our work. All of these areas are open access, so anyone wishing to use the simulators can gain access to the classroom and the information held in Second Life.

Activity 2

This was followed by an evaluation of the simulations that had already been developed for the Faculty of Health and Life Science. In order to do so, several avatars were gathered together and videoed in Second Life. This allowed the author to review the simulation and to map the learning outcomes achieved against the outcomes of the level 3 module they were designed for. The final simulation chosen was one surrounding issues encountered by a Care Home in the event of a virus outbreak. The students take on the role of a senior management team at the Care Home and have to develop a strategy to deal with control and containment of the virus and how they are going to communicate their situation to the outside world.

Activity 3

Once the author had an idea of the actions involved in the simulations she was then able to assess which of the required learning outcomes and indicative content of the PM module could be covered by use of a simulation. These were:

1. Learning outcomes addressed:
    - Define the aims and objectives of a project
    - Identify the effect of the project on stakeholders
    - Select PM tools and techniques and methodologies to use

    This represents three-quarters of the learning outcomes for the whole module. The areas deemed unsuitable for this simulation were those centred on procurement and detailed strategy development.

2. Indicative content practiced (NOT theory taught):
    - Setting aims and objectives
    - Stakeholder management
    - Project communication
    - Risk identification
    - Risk analysis

    This was just under one-third of the whole indicative content of the module. Whilst there were other areas that could have been covered with simulation it was decided to limit the indicative content and focus on these. There were several reasons for this, including a limitation on time for the execution of the simulation and the knowledge that these are areas with which students regularly struggle.

Activity 4

Within the simulation several pieces of information were provided through objects (a newspaper, a filing cabinet)

and various touch panels in the ALL classroom. These had to be modified to be more suitable for the new PM simulation. Once this was complete the simulation was recreated in the ALL classroom.

Activity 5

Three pilot groups of seven volunteers were formed. These included a mix of nationalities, gender and ethnicity. All had completed the level 3 PM module in that academic year. Group sizes were dependent on how many students volunteered to attend the session and their availability. The original plan was to run one session with all 21 students, but it was decided that the simulation would run more effectively with six to ten students. The three groups also offered the opportunity to pilot different amounts of support. Each pilot group received a half-hour's training on Second Life to introduce them to the avatars and how to operate in a virtual world. Whilst the students were all in the same room, they were instructed not to communicate through any medium other than the virtual world. Each of the pilots was run in a slightly different way:

- Pilot 1: very basic introduction with minimal intervention
- Pilot 2: deeper introduction but minimal intervention in Second Life
- Pilot 3: deeper introduction and facilitating avatar in Second Life.

The basic introduction to all three pilots included a sheet of A4 that explained the simulation and the learning outcomes that it was designed to review. At the end of each session, the students were asked to complete a questionnaire to give feedback on their experience. The questionnaires were those that had originally been developed and used in the Health and Life Science simulations because they were robust and tested and also allowed some comparison between the two simulations.

Activity 6

In the final pilot, a Project Manager from a large international defence company with an interest in Second Life joined the group and reviewed and assessed the simulation from an industrial perspective, giving further feedback on its operation and usefulness to industry. Possible mechanisms for assessment were discussed and decided upon, including the facility for students to take snapshots of the whiteboard containing their work to send to the module leader. This would allow the same type of assessment as that presented by students who engage in the module but who do not engage with the scenario on Second Life.

Evaluation of the project overall was three-fold. We were primarily interested in the fundamental question "could PM be taught in this manner?" Secondly, we were interested in the students' reaction to being taught in this manner and, finally, we wanted to understand industry's perception of what we were attempting to do.

Several evaluation techniques were used; observation, questionnaire and focus groups. Each running of the scenario was recorded, allowing us to revisit how the students responded in the scenario. This will allow us to generate further research. In previous Second Life research projects several questionnaires have been developed to assess participants' reaction to the work and these have been tested and refined. It was decided to use one of these pre-developed questionnaires to record student feedback. Finally, informal focus groups were run with all of the students and the industrial partner to obtain further feedback for the project.

General findings

- Training in Second Life was not an issue; all students managed it in a very short time
- Language was an issue as some of the words in the material had to be translated (for the majority of students English was not their first language)
- In Pilot 1, the students struggled due to lack of information. Technical problems included the fact that the island was closed down by Linden Labs in the middle of the pilot. This was unavoidable, but unfortunately unknown to us

- Pilot 3 was the most successful in that the students progressed furthest in the task and began to tackle more of the PM materials and issues. It should also be noted that a contributing factor could be the experience of the facilitators and the results of Pilot 1 and 2
- Some students returned to Second Life after the pilot, although it is not yet certain why or what they actually did.

Student feedback:

- 'Improve the whiteboard'
- 'I hadn't thought that it was going to be so interesting; I thought it would be boring but it was really interesting'
- 'Great idea – worth developing this tool'
- 'This was extremely interesting and fun'
- 'The only problem for me was that there were too many other things to do to distract you from the main objective'
- 'I do not think that virtual worlds are any good for teaching in. The interaction with people should be part of the task'.

Industry feedback:

- 'Would have expected to see verbal communication possible' (this is possible in Second Life if headphones are used)
- 'Great scope for other training aspect, particularly named were brain storming, 6-sigma and bid/proposal planning'
- 'Use of the facilitator was a definite requirement'
- 'Whiteboard needs to be more functional'
- 'Wanted to see more of how the simulation fitted into the grand scheme of the module as a whole'
- 'Suggest the possibility of several interlinked simulations relating to the same underlying story'.

The key outcomes of the project were:

- Successful building of the new engineering building in Second Life
- Successful mapping of learning outcomes against actual activity
- Successful transfer of a previous scenario into a PM scenario
- Well received pilot which, when evaluated, was enjoyed by the students and seen as a useful learning tool
- Positive feedback from industry regarding the teaching of PM in this style.

This pilot has shown positive results for the teaching of PM in Second Life and shows that it warrants further investigation. The feedback from the students suggested that they had an improved learning experience in this environment. One reason for this could be that they were all inexperienced in Second Life and were not encountering the differences often encountered in multicultural group work.

When the potential assessment possibilities are reviewed against the assessment of the current module, what can be seen is that students provide written 'aims and objectives' for their project, a work breakdown structure, communication plan and risk analysis. It would be feasible to use the model previously piloted in the original Health and Life Science scenario, where students set up their work on the whiteboard in the Second Life classroom and email it to their lecturer. It would also be possible for the lecturer's avatar to engage with students in the classroom and mark their work directly from the board. This is an area that requires further investigation.

With the current pilot there is no solid evidence that engaging in Second Life actively increases a student's employability. But what can be noted is that the industrial participants saw positive benefits by having students engaged in this activity and the students volunteered in order to enhance their CVs and highlight that they had engaged in activities other than those in the basic curriculum.

Although there is not much in this project that would be done differently, it would have been beneficial to have run the pilots earlier and then have the option to run the scenario with students while they were actively engaged with the module, rather than after the module had been completed.

Internal funding has been supplied to develop the engineering building in Second Life. Investigations are under way to look at other areas of the curriculum that can be taught in Second Life, with a focus on disaster engineering. Work with Engineers Without Borders to look at support material for their volunteers before placement overseas will allow the use of scenarios that cannot be implemented in real life.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/engineering_pm_simulations.pdf**

Industrial dissertation for professional engineers

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A synopsis by the editorial team

Abstract

The Industrial Dissertation for Professional Engineers (IDPE) project was aimed at practicing engineers of any discipline who were not currently meeting qualification/training requirements that would enable them to achieve CEng status. IDPE worked collaboratively with FE colleges, the North West Universities Association, the North West Aerospace Alliance, the North West Automotive Alliance, COGENT, the Institute of Mechanical Engineers, the Institute of Chemical Engineers and industrial partnerships and targeted more than 200 North West regional employers. It provided an industrially-based dissertation (HE6/HE7) and extended outcomes from Higher Level Skills Pathway programmes. IDPE helped aspirational people seeking career progression and chartered status whilst they remain in their workplace to identify any of their relevant academic shortcomings and bridge key personal knowledge and skills gaps. Through IDPE, individuals enhanced their knowledge and skills and experiential profile and gained 120 HE-level credits. Guidance was provided by an academic tutor and an industrial/employer mentor and support via e-learning and other materials.

Keywords: blended learning, Chartered Engineer, STEM, PDP, UK-SPEC, engineering

The Industrial Dissertation for Professional Engineers (IDPE) was provided at postgraduate level and its purpose was to develop professional engineers in terms of both academic endeavour and relevant skills, as detailed in the 2011 UK-SPEC and the IMechE publication *Meeting the Challenges and Demands and Supply of Engineers in the UK*. It enabled non-graduate and graduate engineers operating at a professional level to undertake an industrially-based dissertation to enhance their opportunities to become Chartered Engineers (CEng). This usually brings with it a mixture of professional opportunities, possibilities of promotion and increased pay and the status of being regarded as having professional standing and credibility. IDPE focused on students who were viewed as possessing graduate-level skills but who may not have had a formal degree qualification.

The background to the concept of IDPE partly arose from working collaboratively with employers and others in the North West (NW) to address shortfalls in specialist engineering skills (relating in the main to advanced composites) for more than five years. During this period, many individuals were identified who were qualified up to/near degree level but who did not have the educational/training background necessary for CEng status. Such individuals typically worked within a company and often found it difficult to study for a postgraduate qualification due to employment or personal issues. IDPE intended to assist this type of student by providing academic delivery in a blended learning environment, supported by academic tutors and industrial mentors. It built on background research undertaken via the Higher Level Skills Pathway (HLSP) programme in Advanced Engineering Composites, mapped against UK-SPEC and the Institute of Mechanical Engineers (IMechE)'s Monitored Professional Development Scheme (MPDS), which enabled individuals to generate a portfolio which facilitated a route to CEng. IDPE consisted of 120 HE7 credits and met the majority of outcomes normally associated with the MPDS (which utilised learning achieved in the workplace via active learning sets with support sessions from university academics and industrial mentors).

The approach to learning for groups such as IDPE students was one of student-centred learning, which consists of elements such as enquiry-based learning, reflective learning, learning how to learn and some didactic teaching. The University of Bolton is renowned for actively engaging disadvantaged groups and IDPE further assisted in that endeavour. IDPE was also, in part, a response to the objectives shared with The Royal Academy of Engineering, identified in its Strategic Plan 2005–2010. The intended outcome of the approach taken through the IDPE methodology was that students would recognise that they may need to learn how to learn, identify areas of knowledge and skills in which they need to develop and make plans for how they are going to proceed through the programme and on to a professional engineering-based career whilst continuing to develop themselves as lifelong learners. Monitoring and evaluation of IDPE was largely provided through university procedures and specific project management.

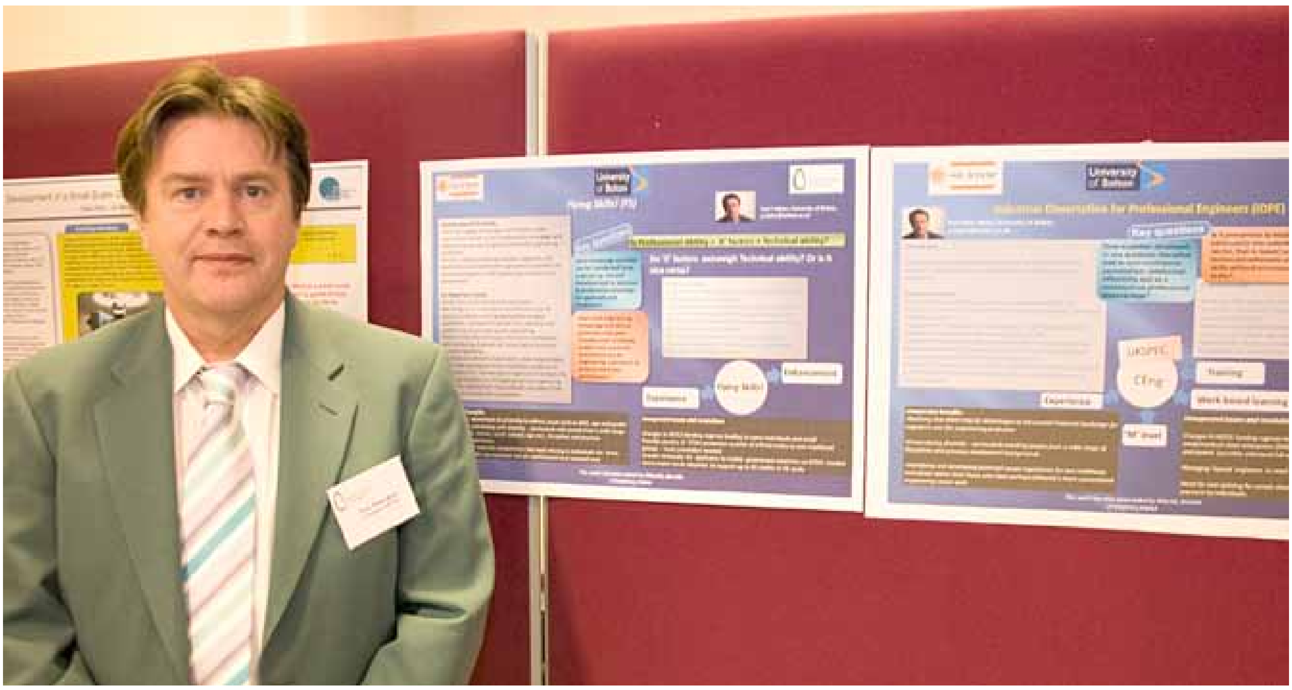
After consultation that involved visits to manufacturers such as Aircelle and Walker Seals, participation in employer fora such as the North West Aerospace Alliance (NWAA), SEMTA and the IMechE and discussion with representatives from industry and associated agencies about issues such as relevant content, assessment delivery and timing of the programme, an overall approach for the IDPE project was agreed in principle. The input from these fora involved consideration and discussion of elements such as timing and duration, flexibility of participation, cost, supervision, content and relevance of individual IDPE outcomes in relation to stated and/or anticipated organisational goals. Of primary concern to industrialists appeared to be issues of technical and business relevance, cost and flexibility. Fortunately, IDPE was able to address these concerns. Issues that were more difficult to resolve included personal and professional reward on successful completion and future opportunities that might arise. The approach used by the IDPE project (which was to initially interview each potential participant) was based not just on the applicant's technical ability, but also on their personal motivation and their potential for working as part of a team at a professional level. The interview process indicated that some potential students lacked personal and professional qualities and attributes, a problem that, if left unaddressed, may hold them back in their careers. IDPE was intended to identify this situation and provide appropriate means of improvement.

The first cohort consisted of a small number of students (approximately 15) who undertook a number of modules in engineering, technology and computer skills, produced a Personal Development Plan (PDP) and received career counselling and guidance where appropriate. Those who successfully completed IDPE were either awarded an Advanced Diploma in Professional Development or, for those with sufficient funds, continued on to a MSc programme.

Initial learning was geared towards setting up students' research and personal skills by guiding them through an e-learning environment. The web-based teaching aid/repository MOODLE was used to drive this activity. For the IDPE project, this process finished at the end of February 2012; since then the students aimed to develop their e-PDP based on UK-SPEC. In conjunction with this, the students also studied a technical module which enabled them to carry out the research element of their dissertation. The benefit of this process was that the students became more self-directed and independent learners. The e-PDP guided the students through their dissertation and enabled them to map against the requirements of UK-SPEC.

IDPE students were assessed throughout the project via presentations and coursework to a small team so as to try to reflect an actual working environment. This process appeared to be much appreciated by the mature students that IDPE naturally attracted, particularly as it seemed to help those returning to education after a lengthy period.

The IDPE dissertation involved the student proposing a technical topic that was relevant to their intended career. This might have involved a project or area of work that the student was involved in at their place of work or an area that the student wanted to move towards as part of their planned career path. On proposing the topic with academics and potential industrial mentors, the student then had to justify (through the provision of appropriate evidence and documentation) the reasons for their proposal. A review of the proposal by academics and mentors then took place and a decision was taken about its technical, academic and logistical viability. Once approved, academic supervisors and mentors were then appointed to oversee, monitor and evaluate ongoing



progress and eventual submission of the dissertation for assessment. This approach also gave students the skills needed to review their technical communications and reflect on their writing. After completing this task, the students were then asked to give a short presentation on their paper to a technical audience of mixed disciplines.

Assessment of the dissertation, when the project was conducted in industry or the workplace, needed careful management and involved using chartered engineers (and/or mentors) within a company wherever possible. These designated individuals verified that the student had completed the work themselves, gave an initial assessment and level indication of the work. This was then marked by the academic tutor(s) involved. When disagreement occurred a third person became involved. The final grade was then subject to an interview assessment viva. This method of assessment was agreeable to most companies that were consulted. Some reasons for the dissertation process (including assessment) seeming popular with employers included the potential for discussion, participation and involvement in academic projects that are related to the workplace and of likely relevance to the mentor(s), the opportunity to understand an academic process, the possibility that a representative from industry may have some influence on assessment criteria and how they might be applied and also the potential for representatives to gain more understanding of how engineering employers could become more involved in collaborative ventures with the academic sector.

75% of the original recruitment target started the programme and were monitored regularly. Certain trends/traits were highlighted. IDPE was successful in recruiting students of the intended calibre and therefore addressed access and flexibility issues of the target group. Some unforeseen issues arose whilst undertaking the IDPE project, but these were largely outside of the control of the project team. Issues included the downsizing of company workforces, which restricted recruitment of elements of the target group, and the ongoing restructuring of the host university which directly impacted on the operational capacity of the project staff.

From interview data, it was apparent that many IDPE students were short on specific non-technical skills which we initially termed 'X-factors'. The students all appeared to have good technical knowledge but were not necessarily what might be described as 'rounded individuals'. Due to this apparent deficiency it was recognised that they may struggle at stages of their career that might require or involve prolonged interviews. The emergence of the 'X-factors' had not originally been anticipated as a consideration; however, the process adopted and used by IDPE should have helped these students to make progress in their future careers. The 'X factor' elements have now been included in the new version of the e-PDP and this was also considered for the validation of the faculty's MEng programme in March 2012.

The main difficulty for the students appeared to be a financial one. To alleviate this, the IDPE programme was split into sections so that the cost can be distributed over a longer period. This approach necessitated extending the period of study, although this was not as detrimental as one might imagine as many of the students had long term aspirations to become Chartered Engineers and were expecting to undertake a journey of some length.

Even though for many students the process took longer than first anticipated, they appeared to be happy in general with their programme. Our approach to teaching and learning, and to the project generally, appeared to be welcomed. Mature returners in particular need more initial support than recent (within the last three years) graduates; however, once they have gained this confidence they can bring greater industrial experience to the educational process which helps students and tutors and enhances the project generally.

The use of online support for the students helped their development as it was provided alongside the help of tutors and not just as a sole aid to learning. It was very useful on an individual basis as it helped them to reflect and focus at the beginning of their study programme.

It would have helped if we had had more time to speak to companies on a one-to-one basis; however, due to cost and time constraints this was not always possible. Working with companies on an individual basis really helped them to gain an understanding of what we were trying to achieve.

In terms of further development, the IDPE project raised some interesting questions about the profile of students who participated, and those who did not, which could lead to further research and study. For those who participated in the project, questions need to be considered, such as are their needs for the missing 'X-factors' to be addressed as part of a wider debate about potential deficiencies in the education and training of professional engineers? And, if so, where should that debate occur? Who should be involved in that debate, what actions should be taken and how should these actions be implemented? And how long would it be before these actions would show measurable outcomes? It was interesting to note that no women participated in IDPE. This may be due to various factors, including the shortage of women in engineering generally, but it could also be related to issues such as the approach that women take to responding to changes and challenges that arise in their professional or personal lives. Whatever the reasons, more detailed analysis needs to be undertaken.

Questions have arisen about the use of mentors and the appropriateness of the viva approach and whether it should be used for all of the assessments. The project team is considering setting up an academic and industry relations board to discuss this process for future assessments in general.

The work done on this programme was incorporated by the University of Bolton in its new engineering programme which was validated in March 2012. The e-PDP and the technical publications are to be subsumed by the new postgraduate programmes and it is also anticipated that the process will be incorporated in the new CPD programmes aimed at the graduate engineer market currently under discussion with the ANSYS® CPD team.

The team is also looking at linking the PDP with the university's social network, as well as international ones. There are currently software conflicts in this area, but we hope to overcome these problems in the near future with new upgrades.

The full case study and literature references can be found at:
www.hestem.ac.uk/sites/default/files/idpe.pdf

"Moving closer" – maximising benefits to university courses, students and employers through undergraduate civil engineering placements

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A synopsis by the editorial team

Abstract

This project built on research from university and employer perspectives exploring relationships between expectations of employers, professional bodies, students and universities on what constitutes a good work placement. Qualitative information on good practice was gathered in order to identify areas for improving placement practice and to illuminate employer engagement processes. Impact and benefits of different approaches to placements and curricula and/or staff Continuing Professional Development (CPD) implications were identified, together with recommendations on how improvements in understanding are shared and disseminated among employer groups and universities. Findings included that, although there were already guidelines on placement practice from a number of bodies, good practice identified at a wide range of points seemed more the result of academic staff drawing on their own experience, formed in the light of good knowledge of professional institution requirements, rather than use of guidelines. Employers mentioned professional institution requirements almost as a matter of course. That guidelines are not used as intended by those that produce them may be a general tendency, but this project's guidelines specifically reflect the organised voice of employers thanks to the involvement of their senior groupings, Sector Skills Councils and similar, in addition to individual employers. This project's guidelines are also more up to date than others identified, including particular issues affecting provision of placements that may face universities over the next few years. Students seem to recognise the benefits of placements more in retrospect than in advance. Some universities seem more flexible than others, adapting provision of placements as economic and other conditions have changed and to meet the needs of employers and placements. As one employer put it, 'employers gravitate towards universities that make it easier'. Employers also want to see academic credit awarded for placement learning and understandable processes with which they can help in support of this. The guidelines will be made available through a number of channels.

Keywords: university-employer views, student work experience, placements, employability, guidelines, communication, civil engineering, built environment

This project originally arose from the realisation that it is beyond doubt that good industrial placements should be integrated within degree courses. A United Kingdom Contractors Group (UKCG) University Task Group survey conducted in 2010 clearly indicated that placements were seen by major construction contractors (who employ many civil engineers) as crucially important to graduate employability and that understanding and communication between universities and employers needed to be substantially improved if a better outcome was to be achieved. A later review conducted for CITB-ConstructionSkills, revealed that employers were still fairly negative about universities' conduct of and support for placements, and that it was increasingly likely that a graduate with no work experience would have little chance of gaining employment in a cognate area. The 2012 Wilson report contended that university culture, strategy and course portfolios offer more likely explanations for the decrease in year-long placements than any of the perceived barriers identified by previous research into their decline and makes recommendations specific to work experience, one of which is that HEFCE should establish a mechanism whereby universities are incentivised to expand "sandwich" programmes through changes to the Student Number Controls that it operates.

When the project was first mooted, it was felt that it may become even more important to enhance understanding between employers and universities about work experience, given straitened resources likely to impact on the propensity of courses to offer and run placements as financial and related changes affect the way in which universities operate. Investigation was based primarily on qualitative research, with the main aim of producing up to date guidelines affirming the expectations of employers and those who take responsibility for the conduct of placements within higher education. The guidelines are available online at **http://www.hestem.ac.uk/resources/**

guidelines-moving-closer. The aim of the guidelines is not to impact placement performance merely through the student but to supportively inform improvement of employer-university communication on placements, fostering a context in which students are enabled to perform well when on work experience and are thus better able to maximize the benefits of their placement, both short and long-term.

The project's initial review drew on a wide-ranging exercise which underpinned the work of the Built Environment Skills Alliance (**https://sites.google.com/site/besaukalliance/**) Higher Education Strategy Delivery Group. Other sources fed in, for example professional institution information was explored and there was substantial examination of existing placement guidelines. The project also ensured links to developments in engineering outside of the built environment, for example with the SSC STEM Cluster (which related to all of engineering).

The project secured three of its employer participants through existing relationships and CITB-ConstructionSkills helped in locating smaller firms for potential involvement. The project set out to work with four employer-university partnerships with active civil engineering placements involving students from the university concerned. The partnership sample reflected a great range of variables which could impact on how employers and universities operate as placement partners, and the views of both sides. The first field work actions were to devise and carry out telephone interviews with employers. Once it was established which university the employer thought appropriate to approach and the relevant name and contact details were obtained, the university was contacted, the project explained and cooperation sought.

Qualitative methodologies were used to increase understanding. These centred on in-depth interviews with the employer-university partnerships. Face-to-face interviews were also carried out with University of Bradford School of Engineering, Design and Technology (EDT) students, intended primarily to provide a baseline for comparison following the pilot of the draft guidelines for the University of Bradford's live placement provision. This pilot did not take place due to an unexpected event which affected the project's operations and communications and delayed the draft guidelines. However, there are plans for future testing in hand.

As it was not possible to pilot the guidelines within live placements, information was brought in by alternative means, for example through the University of Bradford's Civil Engineering Industrial Advisory Board and at an Employers' Fair organised by Bradford's School of EDT. The project findings were also presented at a showcase and included in a staff briefing and a Project Directory produced for wider dissemination by the HE STEM Office, all at the University of Bradford. The guidelines were fully reviewed by the Institution of Civil Engineers (ICE), the most immediately relevant professional institution (and other Joint Board of Moderators (JBM) professional institutions) and by the Construction Industry Council (CIC), which works across the majority of professional institutions operating in built environment subjects. The Chair of Bradford's Civil Engineering Industrial Advisory Board, a senior academic who was not otherwise involved with the project, also provided comment. The guidelines were examined by a leading member of the relevant UKCG committee who also chaired the final seminar. At this seminar, having attended presentations which included the project's processes and key findings, and with the main points of the guidelines available, a wide range of attending stakeholders considered areas organised by four different discussion topics which related their conversations to the project's objectives. This led to the production of a number of "Big Ideas", crystallising potentially significant additions, most of which were included in the guidelines.

From the employer-university partnership interviews, it was ascertained that, though guidelines for placement practice exist, it seems that academic staff draw primarily on their own experience, formed in most cases in the light of good knowledge of professional institution requirements. Employers mentioned professional institution requirements almost as a matter of course, but not the use of placement guidelines such as those identified by the project.

Good practice was identified at a wide range of points of the placement process, from initially working with employers through matching student with placement opportunity, establishing and upholding a meaningful placement learning programme, development of generic employability and specific occupational skills, identifying opportunities for and then securing evidence of learning and achievement, visits and what happens in them, supporting first steps towards professional qualification and tying off and learning from placements. Potentially transferable points about universities working with smaller firms were also uncovered - and much more.

Some universities seem to have adapted placement provision as economic and other relevant conditions have changed. They also appear more likely to flex to employer requirements, for example by rearranging modules to cover in advance what will be required of students on placement and address specific employers' requirements, individual placements and professional institution objectives. Furthermore, these universities tend to have staff development strategies aimed at improving academics' placement practice. Universities are also using technologies which facilitate reporting for student, university and employer; in one case this reporting is fortnightly. Factors like these could place universities well should the profile of substantial work experience as part of undergraduate courses rise.

The award of academic credit for placement students' achievements seems a sticky subject for many in higher education, but the case for genuinely new thinking in forming processes to support this could be strengthening. Employers definitely want to see academic credit awarded for placement learning, and understandable processes with which they can help in support of this.

Student respondents were unanimous in their support of the placement year. Of the students who did not take a placement year, most acknowledged in hindsight that a learning opportunity had been missed. The students currently on placement were particularly appreciative of their work experience. Students seem to appreciate the benefits of placements more in retrospect than in advance and it can take a while after placement for students to form a balanced picture (six months seems about right). These perceptions seem highly valuable, particularly in terms of encouraging and guiding students who are considering or about to go on placement. These views may also be a welcome contribution to a university's public information.

In conclusion, these guidelines differ from others examined by the project in a number of respects. Other guidelines do not seem to reflect the employer viewpoint to the same extent or take changes to higher education funding into account, possibly because they were composed some time ago. This project's guidelines are up to date and ready to help universities meet particular challenges that may arise over the next few years. However, it was obvious that although the academics interviewed were outstanding placement practitioners, they were not necessarily drawing on any guidelines but relying mainly on their own extensive experience. That guidelines are not used as intended by those that produce them may be a general tendency, but this project's guidelines are connected, perhaps more influentially than others, to the organised voice of employers, particularly through the link to UKCG, and also to SSCs and similar. Another difference between the formation of these guidelines and others is that this project's team may have featured a greater amount of expertise in work-based learning and assessment outside as well as inside higher education. This may have enabled identification of seemingly new points relating to work-based assessment. Possible examples include universities asking employers for experiences with potential for students to produce evidence of prized abilities, such as demonstration of capacity to evaluate profitability of possible jobs, handling of logistics procedures and demonstration of safe practice – something which is also a key commercial aspect. Another point related to students being enabled to identify and secure critical pieces of evidence of achievement and then form a realistic picture, at a reasonably early stage of their placement, of what they could gain overall from the experience that would help them in establishing their professional career. Reference was also made to a possible disjuncture between what is achieved by the student on placement and during their degree studies. Vagueness about what party was responsible for aspects of students' assessment while on placement was one indicator of this.

The guidelines will be made available through the following channels:

- *Higher education:* ACED; Council of Heads of Built Environment; Association of Colleges Higher Education Academy Discipline Lead for Construction and Built Environment; Engineering Professors Council; HEFCE

- *Employers:* UKCG; individual employers; SSCs and similar
- *Professional institutions:* ICE; Institution of Structural Engineers; Institution of Highways and Transportation; Institution of Highway Engineers and Chartered Institute of Building; JBM; CIC.

Whilst the delay in finalising the guidelines made it impossible to fully pilot them within the University of Bradford's placement provision during the project's timescale, the project's main outputs were otherwise achieved. Additional review measures were put in place, with plans for further development of the guidelines, again within the University of Bradford. Information acquired by the project on impact and benefits derived from different approaches to placements, the implications for curricula and/or staff CPD and the correlation with professional institution requirements will form the basis of pilot implementation within the University of Bradford during the next academic year. This should help to improve the guidelines and support their transferability to engineering disciplines other than civil engineering.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/moving_closer.pdf**

English language and critical thinking support for students from diverse backgrounds

Professor John Parkin

Department of Urban Engineering, London South Bank University

A synopsis by the editorial team

Abstract

Feedback to students which is valid, reliable and helpful is critical to their intellectual development and progression. Engineers communicate and generate ideas in a variety of ways, and language is an important medium requiring a high level of ability in clear communication and critical thinking. There is diversity within the student body in terms of its ability to communicate effectively in writing. A series of surveys of students and employers was undertaken, including a focus group with employers and various timetabled sessions with students. Arising from this work, a framework for providing more appropriate feedback to students was developed.

Keywords: technical writing, critical thinking, feedback

As writing is typically taught prior to attendance on an engineering course, students who lack the ability to write and reason within the discipline can expect little additional support in developing their written communication skills. Some may regard writing as a so-called "soft" skill; however, most researchers in engineering education recognise the strong link with intellectual development. The CBI identifies literacy, which it defines as including the ability to produce clear, structured written work, as an employability skill, and notes that employers were 'not overly impressed' with graduates' literacy skills, suggesting that a gap remains between output and expectation. There is a need for better literacy within the engineering profession and work remains to be done to develop appropriate valid and reliable measures for assessing critical thinking and written English.

Dr Ruth Van Dyke's work at London South Bank University concerned fluency in English in relation to identifying why there are differences in ethnic and gender degree attainment. This work confirms other research which suggests that there is a statistically significant negative effect on degree attainment for those from BME groups.

The aim of this project was to develop innovative practices in providing feedback on written English, based on trials with a diverse community of students studying a Railway Engineering HNC part-time. The cohort of 16 students was in the process of undertaking a railway engineering project. Assessment included writing a discussion of the problem to be tackled and the resolution of that problem by engineering measures. The exercise in developing feedback was focused on the initial 500-word problem statement and allowed for marking and then a period to review the feedback with the students. The cohort comprised five native English speakers. The mother tongue of the remaining 11 was as follows: Afrikaans (two), Albanian (two), Bengali, Czech, Hausa, Konkani, Portuguese (Angola), Urdu and Yoruba. The Bengali and Urdu speakers were educated in the UK, the Hausa and Yoruba speakers were educated in English in Nigeria and the Konkani speaker was educated in English in Kenya and India. The remaining six students were educated in their mother tongue in their home country. Two students had four languages, three students had three languages and seven students had two languages. The English students had the least broad language skills, with four of them only having one language.

The project's aim was supported by the following objectives:

- To engage with employers to assess their requirements with regard to critical thinking and written English skills for graduates working in engineering industry
- To benchmark the performance of current students against each other and other cohorts within the department
- To develop criteria for marking technical written English with precise and supportive forms of commentary and feedback that are valid and reliable.

The approach adopted was to survey students and employers and to develop a feedback form with feedback on this form from students.

The students were asked to rate their ability in listening, speaking, reading and writing in each of their languages. A general pattern emerged: they rated their listening and speaking ability more highly than their reading and writing ability. English dominated as the reported second language. The average scores, unsurprisingly, were less than for the primary language, but interestingly the average score for reading was fractionally greater than for speaking.

The majority of students wrote emails and reports. Other forms of communication included, to a lesser degree, writing letters, specifications, method statements and quotes and minutes. More than half wrote for an internal company audience, while fewer wrote to clients and suppliers and sub-contractors.

Students were asked to rate the order of priority of aspects of written work. Responses were as follows (highest priority first): i) comprehension, ii) clarity, iii) precise use of technical terms, iv) conciseness, v) logic of argument, vi) and vii) (equal) precise use of words and spelling, viii) ordering, ix) lack of ambiguity and x) precise use of verbs.

Students were asked to comment on the feedback form currently used for giving comments on written English. They were asked to state whether or not they understood the comment being made and, if not, to rate its importance.

The feedback which students understood least (with less than half saying they understood) is as follows:

- Singular nouns always conjugated with singular verbs and vice versa
- Verbs conjugated in appropriate tense
- 'Data' always with a verb conjugated in the plural
- Reference with multiple authors (e.g. Name et al.) always with a verb conjugated in the plural
- In text: three or more authors referenced as 'Author1 et al. (year)', authors initials not quoted.

It is probably the grammatical term 'conjugate' which is causing confusion. Other points which only around half of students understood included style points in choice of words and points relating to Harvard referencing.

With one exception, the average score for importance was always greater than 3.00, indicating that students generally thought the points had some level of importance. The most important was the use of punctuation (full stops, commas and so on being used appropriately) and the least important was the point about the slash never being used because it has no grammatical meaning.

Overall, it can been seen from answers to the twelve to fifteen questions on the initial survey that students have neither knowledge of grammatical terms, nor an understanding of feedback when grammatical comments are made about their work. Clearly, a development of the form would require any grammatical terms to be explained.

A focus group of civil engineering employers was held as part of an Industrial Advisory Panel meeting in February 2010. The group comprises senior figures from a range of backgrounds and the discussion, based around four generic questions, was led by Ruth Van Dyke. The following section summarises the employers' responses against each of the four questions:

- Employees need to write *curricula vitarum*, 'standard reports', and various internal and other work-related documents such as business letters and emails
- The audience for the written work might be future employers, work colleagues, the engineering

community and a wider group with less extensive or limited engineering knowledge. The audience may be professional or lay and the style should be objective and logical

- Where the audience is within the engineering community, use should be made of appropriate terms (engineering language). Where the report or letter is for lay-people then information has to be expressed in terms that they will understand
- Written work should be written clearly and this is best achieved by simple, clear and precise language with short sentences and good punctuation. If acronyms or abbreviations are used then they should be explained so that they are understood by all readers. Overall, reports and letters should be concise
- All communication in an employment setting should include correct spelling, sentences written in accordance with the rules of grammar and adherence to the rules of punctuation
- Very importantly, a point was made which relates to critical thinking. Employers suggested that there should be an ability to identify and develop options which ought then to be evaluated in an objective way
- Writing that would be deemed poor is often written in an emotive rather than an objective style and may be personalised and similar to that which may be found on social networks or in text messages
- It is too easy with word-processors and email for communications to be sent without having been checked for spelling, clarity, grammar and logic. Employers recognise that they have to review what has been written, but this view is not always understood or shared by employees. One comment suggested that 'technology has made us lazy'
- Other examples of poor writing occur when writers do not understand their audience or what is entailed in producing a standard report.

In addition to the consultation with students and employers, valuable comment has been made by both John Seely (London South Bank University Faculty of Engineering, Science and the Built Environment) and Graham Barton (who works in a specialist English support unit at the university). A revised form has been developed which has arisen out of development and use by John Parkin, the consultation with the students and discussions with these other expert staff.

In terms of assessment, the revised feedback form was used with the HNC Railway Engineering students on a short piece of written work they submitted as part of the railway engineering project. It has also been used to mark the BSc (Hons) Civil Engineering final year design project submissions.

After the written work was handed back to students, they were asked to comment on the form by hand-writing comments across it. Most of the feedback consisted of tick marks. Other positive comments included things like: 'common mistake' and 'always struggle with this'.

In the future, the feedback form that was developed as part of this project should continue to evolve and become embedded within the department. There has also been the opportunity to use the form as part of a new cross-faculty first year *Design and Practice* module which introduces students to technical writing. As part of this module, the form has been used with over 500 students on a piece of writing used as a diagnostic test at the beginning of the year and will be used for a further essay at a later point.

To summarise, educators need to ensure that students are aware of the standards that they have to achieve. This process should commence at the very outset of the students' time on the course and may require time to be set aside specifically to work on writing so that they can be explicitly taught, for example, the rules of grammar.

A further important challenge is to reach a point where students recognise that writing is an important core employability skill and understand that poor quality *curricula vitarum* and job applications will affect both their ability to find work and their promotion prospects once in employment. This is challenging, but success here would provide the motivation required to spend the time necessary to gain the skills required.

It is also necessary to teach students not only about what constitutes good writing, but also about the required general approach to writing. This includes the ability to: a) generate the ideas about what will be written, b) develop a draft and, very importantly then, c) to re-read what has been written in order to make it clearer and more succinct.

Educators should ensure that students receive appropriate feedback to enable them to understand where their strengths and weaknesses in written English lie. In addition (and this could be quite challenging), there is perhaps a need to provide feedback on the processes in which the student has engaged to develop a piece of written work. This may include a requirement to submit both initial and final drafts so that the development of the work can be evaluated by the tutor.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/english_language_support.pdf**

Showcasing and extending student-led employer-focused extra-curricular activity

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A synopsis by the editorial team

Abstract

This case study describes a project which showcased and extended student-led employer-focused extra-curricular activity, building on earlier work which encouraged the formation of groups of students who were interested in undertaking these kinds of activities. Students at Loughborough University were invited to submit proposals for activities and funding was provided to successful applicants to enable them to jump-start their ideas. Imperial College London has well-established activities and Loughborough benefited from the close working relationship that developed between staff and students across the two institutions. Showcasing and extending student-led, employer-focused extra-curricular activity is a joint venture undertaken by Imperial and Loughborough. Students from each institution worked together to host two student-led symposia, one at Imperial and one at Loughborough.

Keywords: **employability, extra-curricular, student-led, symposia**

At Imperial College London, student-led employer-focused extra-curricular activities are sophisticated, longstanding and varied, from automatic membership of various student engineering societies, which often have a careers emphasis, to student-led projects (since at least 2003) in which an estimated 200 students involved in or supporting projects or project proposals in any given year try to make a practical difference to the wider community by using their engineering know-how. From 2008, the dedicated 'Tutor for Student-led Projects' has been providing support to any engineering student who undertakes student-led activity but, being student-led, there is little bureaucracy attached to these projects.

At Loughborough, these activities are in their infancy and were initiated with previous HE STEM funding and assistance from staff and students at Imperial College during the 2010/11 academic year. There are approximately 45 students at Loughborough involved in these activities, supported by staff in the Centre for Engineering and Design Education (CEDE).

Whilst many academic staff recognise the potential for student-led projects to develop employability skills, the Imperial experience showed that students do not always recognise the employability enhancement that their work brings to them as they are focused on the engineering work outcomes rather than their personal development. In essence, the overall aim of the project team was to create a mechanism whereby groups of students, staff and other stakeholders from within an institution or beyond would have a reason to interact and develop understanding and skills while sharing learning and helping to sustain and extend individual student-led groups. The student-led symposia initiative was conceived through the idea of creating a sustainable student-centric platform for academics, students and employers to engage with each other, enhance the academic credibility of extra-curricular activities and foster cross-institutional student interaction. The expected benefits to the students are increased retention and enhanced employability prospects gained through the organisation of the activities themselves, the organisation of the symposia and contact with prospective employers. A more detailed list of benefits for both universities and students will be made available at **http://cede.lboro.ac.uk/studentledactivity**. Conference and journal papers have also been submitted.

Being student-led activities, it is important to first consider the students' approach. Staff at both institutions issued an invitation to all students involved in activities to consider hosting a student-led symposium and to submit an expression of interest if they wished to be part of the organising committee. Once the committees were established, each group was allocated funding to cover associated costs such as gifts for presenters, competition prizes and promotional items.

Staff offered guidance to the students and were available for help if required, but did not interfere with the programmes for the symposia. Three meetings were held: one at the commencement of the activities, a second mid-way through the organisation period and a final one just before the event. Guidance was in the form of a checklist designed to help with the organisation of the events and the setting-up of conference committees. Assistance was provided with the booking of rooms as students were not able to access this facility. Rail tickets were purchased to enable students from each institution to travel to the symposia. The student committees determined the food that they wished to provide; however, it was purchased by staff rather than the students as this was found to be less expensive.

The main difficulty for staff at both institutions was to stand back and leave the organisation to the students.

This became extremely trying and nerve-wracking as the dates for each symposium approached and the students had a long list of outstanding or incomplete tasks. However, one valuable lesson learned by staff was that a last-minute approach does not necessarily prevent success. Students can - and will - work all night to complete tasks and are surprisingly ingenious. They requested little help or guidance and repeatedly tried to reassure staff that everything was under control.

The first symposium, organised by students at Imperial College London, was entitled *Global Citizen Symposium*. The programme had a keynote speaker from Global Poverty Action, panel discussions on exploring key aspects of setting up and running projects and workshops on exploring how to make the most of a project. There were 55 delegates, including staff and students from both Loughborough University and Imperial College London and invited speakers. Details of the event are available at **http://www.student-ledprojects.co.uk/**

The second symposium, organised by students at Loughborough University, was entitled *Loughborough Symposium* and attracted over 30 delegates (staff, students and employers). The lower attendance rate was mainly due to the timing of the event (immediately after exams and outside of the academic year). The symposium website can be found at **http://loughboroughsymposium.co.uk/Home.html** and further details are available at **http://www.youtube.com/watch?v=jakbi3KrM_4**

In addition to the programmes organised by the students, a workshop delivered by staff from Imperial and Loughborough was run for staff from other institutions who were interested in setting up student-led activities (attended by 13 staff from eight universities).

The staff approach to the development of the symposia (inferred above) is summarised in the following, remembering that this is a student-led activity and that staff support rather than lead:

- Obtain institutional support for the scheme and make links with relevant staff and units, including the Student Union. Establish how the committee will function – solve potential funding and insurance issues before you start
- Engage the students: invite students to form a committee to run a symposium. Use previous symposium information to inspire potential members, take time to find the best route to engage students within your institution. If membership can be drawn from other relevant student groups, this will help provide content for the symposium
- If possible, provide funding to support the event for the first time. Encourage the students to seek further sponsorship
- Encourage a formal submission so that the students have to write down what they want to do and really understand what they are committing to. This could include a requirement for the students to evaluate their experience and obtain feedback from the event
- Introduce the students to previous symposium information (sample feedback forms, checklists for setting up events, etc.). This helps to set a standard and make sure nothing crucial is missed
- Provide practical help in areas such as setting dates and booking rooms
- Provide a listening ear at all times but don't do the work for the students. Discuss progress with the students but it is their responsibility to make the event happen and be a success
- Attend the event and bring colleagues along with you.

A more general guide to support staff who wish to set up student-led activity in their own institution is under development in the form of a checklist and will be available from the authors. Supporting information is available from **http://cede.lboro.ac.uk/studentledactivity**.

The symposia provided students with the opportunity to disseminate their activities beyond the confines of their own project and institution. They also had the opportunity to develop working relationships with employers and staff and students from their own and other institutions. The main challenge was for the students to find suitable dates for the symposia, as it is essential that there should be no conflict with timetabled lectures, tutorials and examinations. A significant benefit to students involved in the symposia organisation was 'real world' experience of, for example, timetabling, financial management, publicity, negotiation, public speaking and networking. Students were able to formalise these learning experiences through participation in each university's employability award scheme.

The Loughborough students found sustainability to be an issue and are being actively encouraged to ensure that there are students from all years of study involved with the running of activities. This should enable a smooth transition of responsibility from year to year.

Evaluation of the project has shown that the students valued their learning experience and considered it to be worthy of continuation beyond the funding period. Additional activities have already taken place and more are planned (see **http://www.student-ledprojects.co.uk/#**).

Feedback forms, produced by the student organising committees, were distributed at each symposium. All feedback, from both staff and student delegates, was positive. Staff at Imperial and Loughborough also separately sought feedback from the students who had organised each symposium and the students who had attended them. The aim was to determine the benefits, achievements, difficulties encountered and disadvantages, as perceived by the students. The feedback received was positive and included a range of perceived benefits as well as some difficulties. It is interesting to note that the students believed that the difficulties they encountered helped to develop individual areas of strengths.

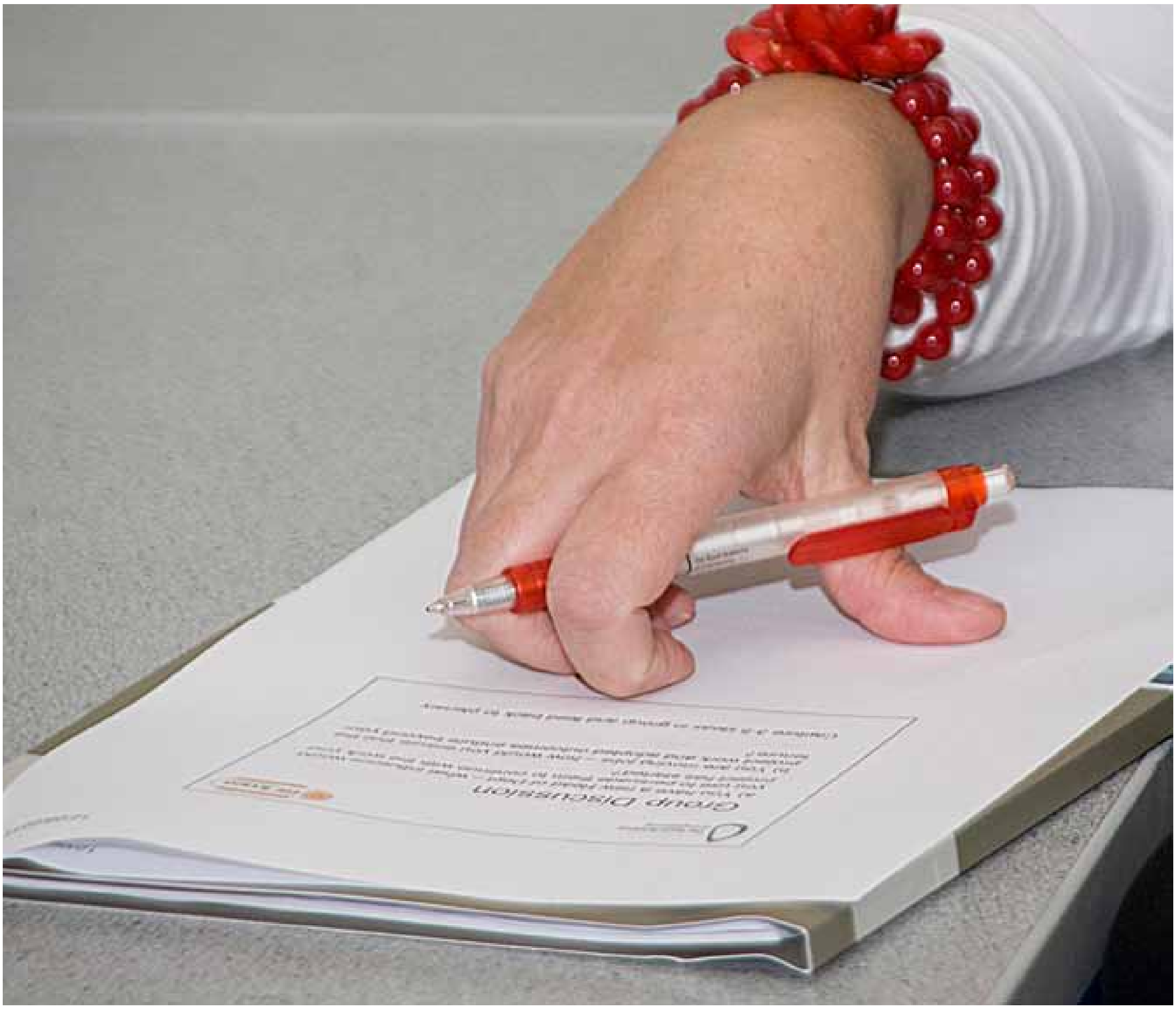
The student organising committees from Imperial and Loughborough both deemed each symposium to be successful and together set up a national student-led projects community. They held a further event in November 2011 (beyond the original aim of this project) and further events are being planned.

Following the experience and lessons learned from the first two events, the students were of the opinion that November would be the optimum time to hold the event, as their academic pressures were at a minimum and the event would hopefully attract a significant number of 'freshers' who would then, if interested, have the remainder of the academic year to become involved in the projects.

We take the student enthusiasm for continuing the symposia beyond the scope of the original project as the strongest indicator of the project's relevance, sustainability and value. Of added value is its function in helping students to appreciate that they have much to showcase to themselves, each other, to academic staff and, inevitably, to future employers.

We have recently been awarded 'Practice Transfer Custodian' status and are in the process of supporting seven institutions to initiate similar activities. Evaluation of these activities will also be undertaken.

To summarise, the outputs and outcomes have exceeded our initial ideas and expectations. The symposia were professional, well-attended and well-received, with the students assuming overall responsibility for content and organisation and continuing to plan future events. There were difficulties encountered with timing the symposia



to meet the project timescales and avoid conflict with academic interests, but valuable lessons, in particular those relating to time management, were learned by the students as a consequence.

If students are to reach their full potential it is essential that staff, whilst being available for help if required, stand back and allow the students to take responsibility and learn from any mistakes that they may make. It is also important that staff do not underestimate student ability and commitment. We feel that the main reason for the success of this project is that the students embraced the idea with enthusiasm and were committed to its success.

One result of the successful symposia is the strengthened cross-institutional working partnership that has developed between both staff and students at Imperial and Loughborough. With the initiation of the national student-led projects community it seems likely that this relationship will continue indefinitely and the project will not only be sustained, but also significantly expanded.

One journal paper and two conference presentations have been submitted. Further work and dissemination is planned. Students from the organising committees will be contributing to the authorship of at least one of the papers.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/student-led_and_employer-focused_activity.pdf**

Exploring engineering thresholds at level 4: what happens in the Oxford tutorial?

Dr Kathleen M. Quinlan (with Professor David J. Edwards, Dr Susannah Speller, Dr Alex Lubansky, Professor Caroline Baillie, Dr Chris Trevitt, Dr Artemis Stamboulis, Mr Johnny Fill)

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A synopsis by the editorial team

Abstract

Educational experts partnered with engineering experts to identify thresholds in learning in level 4 engineering and materials classes at Oxford. *Threshold concepts* is a term used by educationalists to describe particular ideas within disciplines that open up new ways of thinking, allowing students to progress in that discipline. Threshold concepts are transformative for students insofar as they change the way that students perceive the field. Often thresholds are particularly troublesome or tricky for students. 14 tutors and eight students were interviewed to: a) identify perceived thresholds, b) explore why and how proposed thresholds were troublesome, transformative and integrative, and 3) discuss their experience of teaching or learning them. The integrative function of Oxford's tutorials gave tutors insight into the integrative and transformative dimensions of potential thresholds. They emphasised discipline-specific thinking processes that evolve over time, including connecting maths and the physical world, modelling problems, estimating and approximating and balancing convergent and divergent thinking. Tutors perceived these common thinking processes as underlying student difficulties with a variety of specific disparate topics. Thus, the tutorial serves an integrative role that helps students to make connections across the curriculum and probe their own understandings. Based on students' experiences of what helps and hinders their learning in the Oxford tutorial system, this case study explored some implications for setting up learning environments anywhere in the sector.

Keywords: threshold concepts, engineering thresholds, troublesome knowledge, teaching strategies

Research participants included Oxford academics who tutor level 4 university students in either the materials science or engineering science undergraduate degree programmes. Tutors are experienced, full academic staff members who have a long-term relationship with a small cohort of between four and six students in their college, often interviewing them for admission and then tutoring them over several years across a wide range of curricular topics. Participants also included students who had recently completed level 4 of their university studies in one of those two programmes.

In addition to lectures and laboratories, students have a weekly tutorial with their college tutor in groups of one to four, although pairs are most common. Tutorials provide an opportunity to review problem sets and clarify students' understanding. Compared to many undergraduate degrees in these subjects, students spend a considerable amount of their time engaged in independent study, including long (six-week) vacation periods between three short (eight-week) terms. Students in the programmes typically come to university with three A* science grades at A-level and have been interviewed by a college tutor to determine whether they are likely to succeed in an environment that demands considerable independent study and critical thinking.

Locally, our goal was to engage engineering tutors at Oxford in enhancing student learning and to support the construction of a community of practice related to teaching and learning in engineering and materials science.

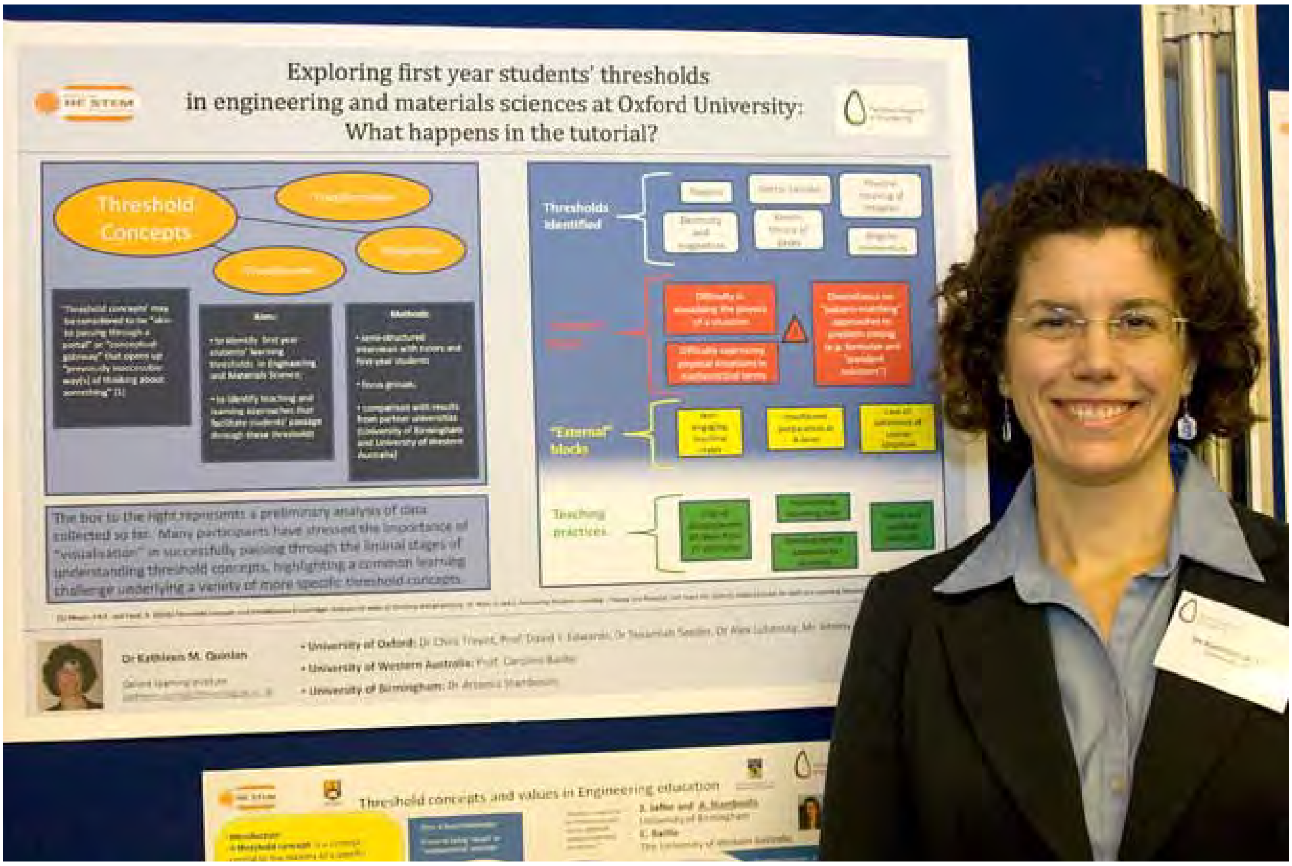
The language of educational research and educational development is often insufficient to capture the interest of scholars whose primary interest is in their discipline; contextualising discussions of teaching within a department and a discipline are more likely to lead to positive pedagogical developments. In the early 2000s, Meyer and colleagues introduced and developed the idea of *threshold concepts*. Thresholds are said to open up required ways of thinking in a discipline, yet are troublesome for students. Students may experience a threshold as troublesome, transformative (fundamentally changing how a student views the field and/or themselves), integrative (connecting previously un-integrated ideas), irreversible (once a student "gets it", they won't unlearn it), bounded (referring to a subset of a discipline), involving a passage or journey characterised by liminality (in which students may feel confused, lost or stuck) and leading to the use of a new discourse. Threshold concepts are useful in focusing students' and teachers' attention and prioritising teaching time in overcrowded curricula.

Threshold concept theory was chosen to frame the conversation because it has a track record of effectively engaging academics in discussions about teaching in their disciplines, although when the project began little was known about engineering students' thresholds to learning. Thus, the project was also designed to contribute to a better understanding of threshold concepts, how to research them and how to use such research to enhance the teaching and learning of engineering and materials science generally. Oxford's small group tutorials offered a unique setting in which to consider the nature of threshold concepts and the teaching and learning approaches that facilitate students' progress through them. Partners from the University of Birmingham and the University of Western Australia (UWA) (separately funded projects) shared methods and results from parallel studies. By comparing and contrasting findings between the individual projects, each with distinctly different teaching contexts, we could learn more about the nature of thresholds (the extent to which they are endemic to a field or specific to particular teaching contexts), as well as refining educational research methods and educational development processes based on threshold concepts which could be applied subsequently to other STEM subjects.

We individually interviewed 14 Oxford academics who tutor level 4 students in either the materials science or engineering science undergraduate degree programme (there were seven academics from each discipline). Tutors were invited to participate if they taught level 4 students and were either recommended by project partners in each division (or another interviewee) or had won an award for teaching. In most cases, potential interviewees were first approached informally by a colleague (typically a project partner in their department). They were then approached by email by a Learning Institute staff member, referring to the colleague who had recommended them or to their teaching award. Most academics who were invited gave their consent and participated in an approximately one-hour interview, typically in their own office. Before the interview, tutors were sent an information sheet which summarised threshold concept theory and asked them to think in advance about what threshold concepts they might like to discuss during the interview.

At the interview, following a brief introduction to the key features of thresholds, each tutor was asked to suggest a threshold that students typically experience during their studies at level 4. The interviewers used a semi-structured interview protocol based on the key features of threshold concepts, although the precise wording and sequence of the prompts varied depending upon the flow of the conversation. Thus interviews asked tutors to focus on one or two possible thresholds that are part of the level 4 course, addressing:

1. Outline the concept and where it occurs at level 4? In which other parts of the course is it significant?



2. What makes it transformative for students? (i.e. How do students think or act differently before and after they understand it? Does the threshold expand or change how students use the language of the discipline?)
3. Does the threshold link a number of key ideas together? (Which ones? How? Where do student blocks generally occur?)
4. What makes this concept troublesome for students? (Giving examples and explaining barriers and why it is troublesome for some students and not others)
5. What helps students master this concept?
6. What is (or might be) the role of the tutorial in uncovering or addressing threshold concepts?

Tutor interviews were conducted from May to July 2011. They were digitally recorded and transcribed *verbatim*. Each interview was conducted independently (i.e. we did not tell participants what their colleagues had proposed or seek reactions to colleagues' suggestions at this stage).

Recruiting students proved to be one of the biggest challenges of the project. The aim was to interview the students of interviewed tutors (who facilitated introductions in ways they thought were most appropriate). However, when this method of recruitment did not yield a sufficient number of volunteers, we advertised focus groups and interviews to all students in the cohort by mass emailing, posters, distributing flyers outside lecture theatres and issuing an invitation during a lecture, using the incentive of complimentary pizza and entry into a prize draw for all participants. Eventually, eight (two engineering; six materials) students were also interviewed, individually or in pairs. The student interviews followed a similar protocol to the tutor interviews, with similar materials sent out in advance, asking students to identify thresholds and following up on the same features on which tutors were probed. However, more attention was paid in the student interviews to their learning strategies, resources and perceptions of the tutorial process. Interviews were arranged and conducted by a research assistant who was a DPhil student in materials science who was familiar with the content matter and closer to the age and experience of the students.

Although we attempted to recruit student participants in June, level 4 students were preparing for end-of-year exams and we only interviewed one student at that time. Most of the student interviews were conducted early in level 5, asking them to reflect on their learning during level 4. Thus they had completed their level 4 examinations and all of the study and consolidation of understanding associated with that. No effort was made to distinguish high or low achieving students in the interview pool. Again, interviews were digitally recorded and transcribed *verbatim*. As the student interviews took place after initial analysis of tutor interviews, we were able to seek students' input on the thresholds proposed by tutors. This was done only after students had an opportunity to reflect on and propose their own thresholds without prompting.

Tutor and student interviews were analysed by carefully reading each transcript and identifying segments of text (a single word or phrase, sentence or larger block of text) that roughly corresponded to different features of threshold concepts which we coded (e.g. "concepts", "blocks/barriers" (for troublesomeness), "transformation" and "teaching") to enable easy comparison of sections of transcripts addressing similar ideas. This enabled the identification of common themes among and across tutors and students. Sub-codes were developed for most of the main codes. This approach can be thought of as a "horizontal" approach to data analysis, in that through the codes we were able to pull out text across any interview that dealt with particular aspects of threshold concepts. This allowed exploration of particular features of threshold concepts. Concepts mentioned in the interviews were extracted and described in a short phrase and then, with the help of disciplinary experts, clustered conceptually into a one-page diagram.

However, this "horizontal" approach did not sufficiently capture the integrative nature of the ideas discussed in the interviews. We experimented with *concept mapping* to better represent the connections between ideas. Concept maps array a set of ideas hierarchically and provide linking words to show the relationships between different nodes on a map. Thus we took key phrases or words from the coded transcripts and visually explored the relationships between them by linking them with arrows and "linking phrases". This approach can be thought of as a "vertical" one insofar as it digs beneath a simple phrase (e.g. a named, perceived threshold) to better understand where the difficulties lie, how it transforms students or how the concept is related to other concepts (integrative).

We invited all tutors in the two departments (via standard departmental listservs) to attend a half-day workshop in January 2012 to review and interpret preliminary results. In addition, individual invitations were issued to each tutor interviewed and to tutors in those and closely related STEM subjects (e.g. physics) who had completed Oxford's Postgraduate Diploma in Learning and Teaching in Higher Education. Fifteen people attended, including project partners, several tutors who had been interviewed previously, some Oxford tutors who had not been interviewed previously and two engineering academics from other universities who were interested in the project and offered an external perspective.

After an introductory talk given by the project partners, the workshop was divided into two parts. In part one, the thresholds suggested by participants (tutors vs. students) were presented to the workshop participants who were then asked to engage in group discussion about their interpretations of the findings. Participants in the workshop were organised into two groups based on their discipline: a "materials" group and an "engineering" group. The materials group also contained two physics tutors. Each group worked at a separate table, facilitated by a project partner. Each group then reported their discussions to the other group. In part two, the Principal Investigator presented findings related to teaching and learning threshold concepts, with particular emphasis on what students found most useful. Participants then discussed those findings at their tables with an emphasis on teaching strategies for progressing over thresholds. Part two was followed by a "reporting back" session. Group discussions were also digitally recorded and transcribed *verbatim*, providing another round of iterative data to verify, clarify and elaborate on the findings.

We summarise our findings here by each of the main research questions:

1. *What are the perceived thresholds in level 4 engineering and materials at Oxford? How much overlap is there between students and tutors?*

   There were more than 40 specific possible threshold concepts mentioned in interviews, including specific ideas within applications of calculus, estimation/approximation and problem-solving, crystallography, thermodynamics and electricity, use of terminology and visualisation. There was reasonable consensus between tutors and students on the topics and concepts mentioned. However, in probing the ideas further in the interviews and in the interpretation workshop, many of the thresholds were traced back to difficulties students had in four tightly connected areas which were common to both materials and engineering science:

   a) Connecting maths and the physical world. Here the problem was generally not in doing mathematics itself, but rather in "translating abstract ideas into mathematics" or "mathematical representation of the physical world". This was one of the most commonly mentioned thresholds.

   b) Approximation and estimation, also described as "back-of-the-envelope calculation" and an "automatic checking system", was one of the most commonly mentioned thresholds. Students who understand how maths and the physical world are related will be able to, according to one tutor, 'appreciate the appropriate approximations which we all have to do to actually produce a new engineering solution'.

   c) Modelling a problem. Many of the tutors (and several of the students – see responses to question 2 below) say that students need to learn the "set-up" of the problem.

   d) Convergent vs. divergent problem solving. Students come into university accustomed to questions that converge on a single right answer. In engineering, real world problems are open-ended; choices need to be made about how the problem will be modelled and the goal is a "good" answer that meets the needs of the situation at hand. Creativity in modelling a problem is valued as a feature of engineering design, therefore students must become more comfortable with uncertainty.

2. *Why and how are proposed thresholds troublesome, transformative, integrative?*

   Tutors' interviews provided information mainly about how the processes in a–d above were transformative and integrative. The thresholds are integrative insofar as they underlie all of "thinking like an engineer". Many of the technically difficult ideas mentioned in the interviews were offered as examples: for instance, one tutor gave numerous examples of situations in which modelling problems is required, including Kirchoff's laws, Newton's laws of motion, Thevenin's theorem, Ohm's law and phasors. It is the thinking process of reducing complex systems that provides links between these disparate technical areas and between different topic areas, including electricity, fluids and mechanics. Thus, the elements highlighted above are highly integrative. They also seem to be transformative to students. Student interviews both confirmed and elaborated tutors' perceptions as they pertained to troublesomeness. Students tended to refer to the specific topic areas although, by level 5, several of them were also able to reflect on the general processes that are common to many of the topics.

   Students, however, reported more specific blocks/barriers to their understanding of thresholds, which can help identify teaching practices that may help teachers achieve their high level goals:

   a) Not explaining why answers were correct or incorrect or skipping steps in a worked solution

   b) Getting lost in a lecture

   c) Abstractions/over-reliance on visualisation (e.g. tensors)

   d) Changing notation (e.g. complex numbers in electrical circuits)

   e) Understanding the physics of a situation

   f) Sequencing (e.g. thermodynamics being taught before partial differentiation)

   g) "Pattern-matching" approach to learning

   h) Separating analogies from reality

i) Difficulty understanding textbooks.

Their comments indicated that lectures can be problematic because the lecturer may not pace their explanations in a way that students can benefit from them. Instead, some of the students reported the value of the lecture notes themselves (which were comprehensive, tailored to what is expected at Oxford and useful as stand-alone study resources). Textbook explanations may be inadequate to address the challenging underlying concepts with which students struggle.

3. *What teaching methods and learning strategies support students in passing over these thresholds? What is the role of the tutorial in the learning process?*

Ten key themes emerged in students' reports of what was helpful to them in passing through thresholds:

a) Working in groups with peers

b) Being able to visualise a process

c) Suspending disbelief/accepting assumptions/ trusting the maths

d) Going through worked solutions

e) Revision/reducing a topic to its "essentials"/ integrating across subjects

f) Focusing on approaching/setting up the problem

g) Helpful structure of the curriculum

h) Independent reading of notes and texts

i) Multiple ways of explaining or representing an idea

j) Tutorials.

Tutorials were reported to be helpful because they i) offer deeper conceptual explanations that respond to students' concerns and problems, ii) make connections between topics studied at different points during the course, iii) encourage or teach other ways of learning (e.g. drawing or using other tools), iv) compare methods of approaching a problem, v) test students' understanding and provide targeted feedback, vi) offer students opportunities to explain how they solved a problem and how they understand things, which clarifies and consolidates their understanding, vii) push students to explain why something works as it does, and viii) allow students to hear different explanations of the same concepts. The students' experiences of tutorials suggest that the emphasis in those dialogues is on ensuring that students have a deep understanding of the concepts underlying the problem sets and the tools to apply those understandings to problems.

By early in level 5, students are aware of the same key issue raised by the tutors: the underlying difficulty in understanding the physics of the situation (and connecting that to the maths) and the need to change from a '"pattern-matching" approach to learning', as one student and some tutors put it, to focusing on learning how to set up and approach problems ("model" problems) in more sophisticated ways.

By working with both the University of Birmingham HE STEM project team and the UWA curriculum development team, we were able to compare research methods and findings throughout the study. These team members served as "critical friends" to the Oxford process, providing peer evaluation and prompts to self-evaluation. In addition to regular meetings and phone conferences across the three sites, we undertook an exercise in which a small core set of transcripts (from Oxford and UWA interviews) that addressed a particular topic (Mohr's Circle) were analysed by each of the three teams using their own analysis methods. This activity enabled not only a critical discussion of the content related to the particular topic, but also a grounded discussion of differences in analytic approach. Thus, through this exercise, we could probe the methods (including the pros and cons of each) that each team was using.

In terms of local engagement, participants at the January workshop completed feedback forms. All participants either agreed or strongly agreed that the workshop: a) met its goals, b) was useful, c) gave them an expanded understanding of or a new perspective on the topic, and d) that the findings were useful/relevant to their own teaching. In open-ended comments, most participants found either the opportunity for discussion with colleagues or the notion of threshold concepts itself to be the most useful aspect of the workshop. The workshop was useful to the research team in clarifying that the participants recognised the broader thresholds (as described in the findings above) as being more "fundamental".

The research illuminated the key connections between a variety of difficult topics in engineering. It emphasised the thinking processes that students must master on the way to becoming engineers: connecting maths and the physical world, modelling problems, estimating and approximating and balancing convergent and divergent thinking. These generic engineering thinking processes are encountered and illustrated in a variety of topic areas that students may experience as troublesome, but it is often this deeper conceptual understanding itself that causes students' difficulties. These connections can best be spotted and taught by tutors; experienced academics who are involved across a wide range of the curriculum. Thus, the tutorial serves a unique integrative role that helps students to probe their own understandings deeply and make connections across the curriculum. While weekly tutorials of such small groups are not feasible for most of the higher education sector, students' experiences of what helps and hinders their learning have significant implications for how to set up learning environments anywhere in the sector. Finally, assessment exercises might focus on seeking integration across disparate topics in an otherwise modular curriculum.

At Oxford, the results will be used to inform educational development sessions related to tutorial teaching. In 2013, we anticipate launching a new Teaching Fellowship Preparation Programme in the Sciences (3.5 days of seminars, some written assignments, culminating in Fellowship of the Higher Education Academy, in line with Descriptor 2 of the UK Professional Standards Framework). We will prepare materials from this project for use in that new course. Discussions about further dissemination within Oxford and in other conferences and journals are ongoing between the project partners.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/engineering_thresholds_at_level_4.pdf**

Investigating the impact of service/social enterprise learning projects and employer involvement in engineering education

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A synopsis by the editorial team

Abstract

In 2007 it was decided to refresh and invigorate a level 7 MEng module in enterprise education in order to improve student participation and engagement. Given the nature of on-going research work being undertaken in the Department of Mechanical Engineering at the University of Sheffield at that time, it was decided to look at projects that had a broader civic and social element as part of this exercise. To that end, various methodologies were considered, including the concept of service learning, defined as 'a method under which students or participants learn and develop through active participation in thoughtfully organized [sic] service that is conducted in and meets the needs of a community; […] helps foster civic responsibility; and that is integrated into and enhances the academic curriculum of the students […] and provides structured time for the students or participants to reflect on the service experience'[1].

Whilst common in the US, this method is less well developed in the UK and very unusual in the delivery of entrepreneurial education for engineers. This project set out to investigate the effectiveness and impact of this technique within a UK HEI using a range of techniques, including interviewing and surveying all stakeholders. Factors assessed by the survey work included the potential for developing enterprise skills, student engagement and the value of external contributors. This paper presents the results of this study, which show that students' expectations of starting up companies increased through the project and that their understanding of a key issue for the project (disability) also increased. Those involved in the teaching and delivery of the module have seen increased engagement and learning outcomes; however, the results of the project were inconclusive in terms of the value of service learning to the students *per se*, with approximately 50% disliking the 'service' element of the module. This requires further work with respect to the fact that the module has shown increased engagement and learning outcomes over previous years, the most obvious answer being that the module delivers in terms of learning outcomes but takes the students out of their comfort zones and asks them to deliver significant outputs whilst simultaneously being under pressure from other modules.

Keywords: service, social, learning, enterprise, employment, internationalisation, teams

1 US Code 12511, 1990.

Service/social enterprise learning is a credit-bearing learning experience in which students take part in a social project that allows them to deploy their engineering design skills while working with 'real' customers, practitioners, employers and businesses to produce a solution to a social problem. This is then presented to judges as a business. The project has been running in this format since 2007. Prior to this, students were given purely commercial projects with no direct personal or civic customer. These projects were well received, but the level of engagement and participation was found to be average. When we implemented the first social project, the number of students who took the module doubled. Initially, it was taken only by level 7 MEng students from the Department of Mechanical Engineering but is now taken by MEng, MSc and occasionally PhD students from all seven departments in the faculty. Through the years, students are repeatedly reported to have benefited from and engaged more with this learning model, particularly in terms of the development of social responsibility. There has been some analysis of this teaching approach but the full impact has yet to be assessed. This is critical to the development of this type of learning, particularly if it is to be embedded more widely in the UK.

Service learning is a type of learning less widespread in the UK than the US and is not common practice in UK HEIs, particularly in engineering. The literature suggests three main potential 'beneficiaries' of this type of learning: students, institutions and communities. The benefits observed during previous investigations concur with this:

- Students: increased satisfaction, engagement and employability

- Institutions: increased level of engagement with the community, external contributors and recognition
- Community: engagement with the university, problems tackled and some solutions developed. Increased sense of receiving help and also of helping the student learning experience.

Understanding the impact of this learning technique in depth was deemed necessary to enabling HEIs in the UK to adapt, implement and make the most of it.

The research methodology underpinning this study is phenomenography, which characterises the qualitative differences in the outcome of students' learning through the students' own accounts of their experience of the module, in whole or in part. This was recorded through interviews and surveys. In addition to the students' experiences, the customers/practitioners/employers were similarly canvassed for their experiences of being involved in this learning model.

More specifically, the study included:

- two student surveys:
  - questionnaire (response rate 100/132)
  - TurningPoint survey (response rate 80/132)
- one focus group of current students (3 students)
- external questionnaire (4 externals)
- customer interviews (1 customer)
- collation and analysis of responses.

At the start of the semester, students were challenged to use their engineering skills to design a product to aid 10-year old local boy Kieron Norton and other people born with cerebral palsy to operate more easily in their day-to-day lives. Students were asked to consider what type of 'human resource' they would need to take their project to successful completion and then to group themselves in teams of 7–10. They had 11 weeks to complete the project.

Assessment was as follows:

A. 10% Group 3-page initial solution and business model. Formative feedback was provided for this piece of assessment.

B. 40% Group business plan report, including a sound structure and a business-like style. This had to include an executive summary and a cash flow projection for the first year of business. Marking criteria were provided to the students.

C. 40% Group poster presentation to a panel of academics, business people and the customer (team members were questioned by the panel) and elevator pitch by a representative member of the team (no longer than 80 seconds). Marking criteria were provided to the students.

D. 10% Discretionary points awarded only when the team provided work beyond that stated as part of the project and which demonstrated a clear level of innovation and creativity.

E. Peer assessment using WebPA, an online peer moderated marking system. Each student in a group marked their own and their team members' performances. The grades given were then used to weight an overall group mark.

Summative feedback was provided for B, C, D and E.

The students were invited to complete a questionnaire at the beginning of their module, in keeping with the requirements of the ethics committee at the university and the data protection act. They were asked to describe, in a sentence, what they thought the module was about. In both groups, they related the module to applying engineering skills to business or business planning, although the design aspect was also considered important. Six mentioned social enterprise. Responses to a further question asking what their expectations of the module were showed that all of the students expected to learn about the business world and how to deal with 'real' problems.

When asked what their understanding of social enterprise was, all students broadly responded that they understood a social enterprise to be one that helped society or people. The students were also asked what their personal understanding of disability was and all responses again indicated a broad understanding of disability (physical or mental limitation of everyday activities). The students were asked whether they had had experience of interacting with people with disabilities and there was a fairly equal division in both groups between those who had and those who hadn't. A further question explored whether the students felt confident that they were able to interact with a person with disabilities in a professional and ethical way. Almost half of the students in both groups did not respond to this question.

The majority of students in both groups indicated that they had not had experience of enterprise education prior to attending the University of Sheffield. Only five compulsory students and three optional students had experience of running a business. However, a third of these students had had experience of enterprise education before attending the University of Sheffield. Almost half of the students in each group indicated that they intended to start a business.

The second survey of the students was undertaken on completion of the module on the day of poster presentations and judging. The method used this time was a TurningPoint Technologies voting stick system. The survey was conducted after the judges had seen the presentations and posters and questioned the students. The judges then left to deliberate and it was at this point that the survey was conducted (i.e. before the awards and prize-giving).

Throughout the response process upward of 70 to 80 students responded out of the 132 undertaking the module. The first question was whether the module met their expectations. 21% indicated that it had exceeded their expectations and 61% indicated that it had met their expectations - an exceptionally good result. However, for 11% the module did not meet their expectations. In response to the question 'did you enjoy this module?' 68% did and 28% did not.

In response to whether, given the choice, students would do the module again, 49% indicated that they would and 40% that they would not (10% were undecided). This is an informative result that requires further exploration, particularly as 75% of the students for whom the module was compulsory said that they would choose to do the module. There seems to have been a change of mind as a result of actually doing the module. This result should also be compared to student satisfaction, as indicated by responses to the first question (82% saying that the module had either met or exceeded their expectations).

Perhaps of more interest is the positioning of the module in the degree. 63% of student respondents indicated that they would have liked to have undertaken the module earlier in their studies. This may also be a factor in the negative responses, along with the fact that very few students had experienced enterprise education before university.

The next two questions were whether there should be more modules working on 'real' problems (72% said 'yes', 20% said 'no' and 8% didn't know) and whether there should be more modules working on a 'real' problem but with a business focus (48% said 'yes', 43% said 'no' and 9% didn't know). There is a drop from nearly three-quarters of the students wanting more modules with a 'real' problem to just under half when that problem has a business focus.

Part of this research was to assess the impact of service/social enterprise learning and the next question was whether there should be more modules working on a 'real' problem with a social enterprise focus. The responses were surprising: 34% said 'yes', 53% said 'no' and 13% didn't know. The assumption that students engage more with projects that have a social enterprise focus is not borne out by these results, even though numerous students provided very positive informal feedback about the nature of the project after the module was concluded.

When asked whether they enjoyed working with students doing different degrees to their own, 53% said they did (26% had no opinion). This highlights a desire for more interdisciplinary and possibly interfaculty modules.

That 26% have no opinion may indicate that these students do not need to think about this as they are already experiencing it.

In response to whether this module had changed their understanding of disability, 45% indicated that it had and 44% indicated that it had not. This may be a reflection of the students having indicated considerable engagement and understanding of disability in the earlier survey. Responses to the next question ('If you didn't before, would you now feel comfortable working with people with disabilities?') confirm this, with 55% indicating that they would. 73% indicated that the module had given them a better understanding of the needs of people with disabilities.

There is a broad understanding of what a social enterprise is. This is not surprising, as a social enterprise can take many forms and for that reason is not specifically defined. This could also explain why 27% of respondents thought that a social enterprise did not fall into any of the definitions. This outcome also reinforces the earlier conclusion regarding whether or not students value social enterprise projects.

The final question was whether the students would have enjoyed the module as much if the project had been purely commercial, rather than having a social and civic element: 50% said 'yes', 15% said 'no' and 35% didn't know. This is perhaps a true reflection, a 50/50 split, which may indicate that students are not as socially motivated as initially thought. The other explanation is that they would be as motivated with either type of project.

In order to expand on the survey, and perhaps get more reflection from the students, a small focus group was interviewed. The participants confirmed the value of team working, particularly teams of mixed nationalities, and that they had expected to learn the basics of business start-up and that this expectation had been met. They confirmed that lecturers from the business world (external contributors) were very important in terms of understanding the basics of business start-up. They had engaged far better with the project because of its social focus, although this took them out of their comfort zone. This finding supports the initial hypotheses. In response to what did not work, they felt that the timing of the module in the last semester of their final year was detrimental. Had it been earlier, they would have had the chance to produce prototypes (not a requirement of the module, but something the teams wanted to do) and submit ideas for business plan competitions. All participants valued self-directed learning in the module and had undertaken no previous modules like this. They felt that immediate feedback from the external customer helped them to focus their product ideas and they welcomed being able to use their design skills in a 'real' context.

Overall, the students wanted a module like this for each year of their degree. They also intended to refer to the module in interviews and on their CVs and clearly understood the skills they had gained from participating in it.

External business people who had contributed to the module over a number of years were surveyed to ascertain their experience of working with the students on the module. All of them not only contributed to the module, but also took part in the judging of the poster presentations. It was deemed important to understand why they, as business people, had contributed to the module over a number of years. Their response fits broadly into the category of enjoying engaging with the students, in particular seeing that their contribution is appreciated, taken on board and used constructively. They all indicated that they wanted to continue having input into the module and that they would also like to increase this input. Additionally, they all felt that the value of their contribution was in being able to share with the students their experience of 'real world' situations in relation to developing products and business start-up. They also indicated that they would like more interaction with the students for the duration of the module, perhaps as mentors. In reflecting on the module over the years, they all indicated that the student engagement was what had impressed them most. On being asked how they would like to have more input into the development of the module, they emphasised the importance of having a 'real project', but would like to have more input into the format of the module and outcomes expected. They would also like to receive feedback from the students on their contribution.

At the time of writing, only one customer survey response had been received: the Woolley Wood School, which participated in the module in 2010. However, the response did offer a very interesting insight in that the customer had worked extensively with volunteering students in the past and had not found it to be a positive experience. Following participation in the module, the customer's subsequent opinion was that their expectations had been greatly exceeded and the experience had been overwhelmingly positive.

In summary, the combination of the application of engineering design skills to address a social problem in a business context in the curriculum is an extremely valuable learning experience, not only for the students, but also for the customers, practitioners and external contributors. Customer experience is very positive, particularly in relation to the businesslike way the students behaved, and the customers were able to make a direct comparison with the less positive behaviour of previous experiences with volunteering students. External contributors from the world of business are critical to this module and learning experience and the majority would like to make a greater contribution, particularly to the development of the module.

Perhaps a major feature of this research is that all groups identified that this model of learning should take place earlier in the curriculum and possibly more than once. This would allow prototypes to be developed and encourage students to enter business plan competitions or even start up undergraduate student companies. There is also the suspicion that a major factor in lack of enjoyment of the module is that it requires a considerable amount of work at a time when students are finalising their dissertations.

This cohort of students did not have previous exposure to enterprise education and at the beginning only a small number indicated that starting a business was an option they would consider; however, at the end of the module

over half indicated that they were now contemplating starting a business and students recognised the need for understanding business/management within their engineering degree. This is very much in line with the direction the government would like to see higher education taking, encouraging a skilled and highly trained workforce to start their own businesses, thereby regenerating the economy. This should therefore make this module a key marketing feature for engineering degrees at the University of Sheffield, and dissemination of the findings to the wider STEM sector is reinforced by this finding alone. However, at the other end of the spectrum, if students are going out into the workplace they need to clearly understand the skills that they have gained from the module. It is often a feature of embedded enterprise modules that students do not fully appreciate the skills they have gained, although they often report that specific reference to such modules has contributed to the successful procurement of internships or jobs. Students need to have a clear understanding from the module outline of what the module entails and need to be able to reflect on skills they gain through this module and how to articulate and record them.

One surprising feature is that the students specifically identified as a bonus not only team working, but also how effective *international* team working was, which in turn has implications for the global marketplace.

Specific areas of this module (e.g. social enterprise, design, etc.) could benefit from a mentoring system, preferably with alumni acting as mentors. Alumni entrepreneurs are clearly very valuable; they are almost peer role models and should perhaps be engaged more in the module development.

There needs to be a more longitudinal study of the student experience in order to fully gauge the benefit of this learning model. It is anticipated that, once they have gained more life experience, students will be able to articulate the benefits of having undertaken it more clearly.

The module leader expects to continue to develop the module and has a lot of anecdotal evidence from many perspectives about how successful it is. However, it is felt that, given its longevity, there is a need to get more foundation on the perceptions in order to take the module in the right direction. As to module development, although reluctant to impose another feedback tool on them, the module leader would like the students to take part in deep reflection on their experience of the module. There is also a need for a mechanism for development of prototypes and for exploring ways in which the two universities can work on this module.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/impact_of_sel.pdf**

Investigation of the applicability of an e-portfolio tool to support final year engineering projects

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A synopsis by the editorial team

Abstract

This project investigated the extent to which e-portfolio tools can be applied to final year engineering projects with a view to supporting the experience from the perspective of supervisor and student respectively. E-portfolio tools allow students to generate, store and share evidence, minute meetings and record reflections as well as helping them to develop generic professional engineering skills. The research methodology combined qualitative and quantitative techniques. Semi-structured face-to-face interviews with eight supervisors and online questionnaires completed by 13 supervisors and 31 students provided the basis for the research. Training on the university's e-portfolio tool was provided for 19 members of staff, while a seminar introducing the project to the final year cohort was attended by 33 students. To conclude, an e-portfolio application was made available to students.

Keywords: e-portfolio, final year project, learning technology

During the course of a final year engineering project (FYEP), students need to apply a variety of skills, including time management, project management and personal reflection. Students can use log-books to demonstrate progress to their supervisors, who may then provide feedback through formative assessment. At Bradford, the FYEP is worth 30 credits and concludes with an assessed report and poster presentation.

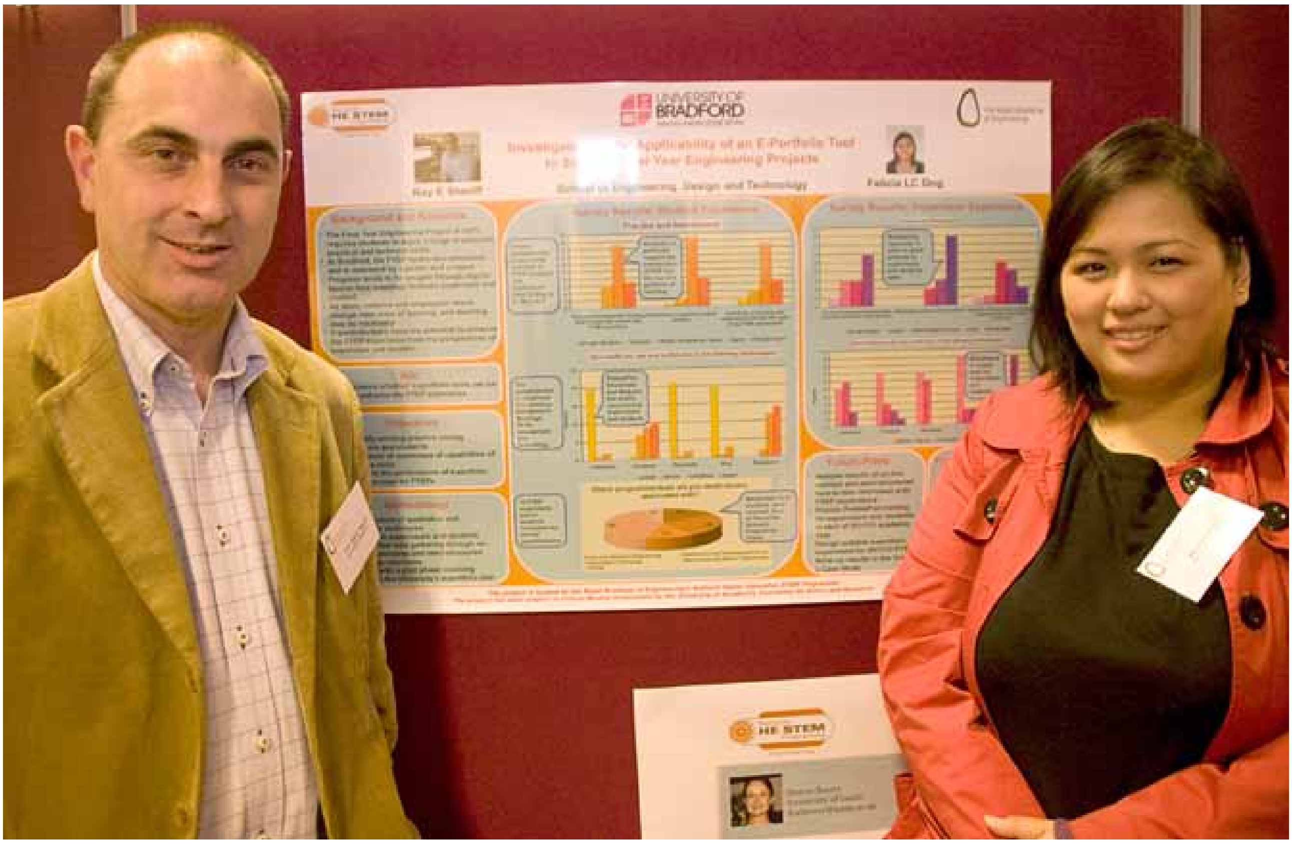
E-portfolio tools allow students to generate, store and share evidence, minute meetings and record reflections and to date have primarily been employed for personal development planning (PDP); however, the capabilities for users to generate, store and share evidence and reflections also offer opportunities for other applications. The university provides students with access to an e-portfolio tool (PebblePAD) for the duration of their studies which features presentations that demonstrate the breadth of innovative applications for which it can be used.

There is possible scope for improving the FYEP experience through the use of e-portfolio tools and it is likely that students will increasingly undertake degree programmes via non-traditional routes in the future. In this respect, regular face-to-face FYEP meetings between supervisor and student may no longer be the norm and e-portfolio tools can use the internet to provide the means for maintaining communication, monitoring progress and providing feedback.

This project extended previous research at Bradford into the opportunities to develop learner autonomy offered by e-portfolios. An inductive research approach was adopted which comprised qualitative and quantitative methods and incorporated an exploratory research method. Prior to commencing the research activity, approval was obtained from the university's Committee for Ethics in Research.

Qualitative data were gathered through eight semi-structured face-to-face interviews with project supervisors (13% of the school's academic staff) in order to determine their approach to FYEP supervision, their familiarity with e-portfolios and their views on the use of technology for teaching and learning. All interviewees were known to the interviewer. The interviews followed a common structure covering: background and experience, meetings with students, the role of technology and project skills and assessment. As far as possible, common interview questions were used, with deviations and additional questions where necessary to accommodate different perspectives. Project supervisors were interviewed in their office environment or in convenient meeting rooms.

Quantitative data were gathered through supervisors' and students' online questionnaires. Thirteen members of academic staff completed the online questionnaire (a response rate of 27%). All returns were considered valid. 31 students completed the survey (a response rate of about 13%). Mechanical and medical engineering had the greatest student representation (at 39%), followed by electronics and telecommunications with 26%. Both supervisors' and students' questionnaires were divided into four sections. For supervisors these were: background and experience, meetings with students, technology and the final year engineering project, and project skills and assessment. For students these were: background, meetings with your supervisor, technology and the final year engineering project, and project skills and assessment. Each section comprised questions in various formats, including the facility for open-ended free-text input as a means of collecting qualitative data. Some questions were mandatory, while others were optional. Closed-



ended questions were used to generate quantitative data. Nominal scales were applied when collecting demographic information. Whenever possible, the same questions were asked of supervisors and students. Returns for the questionnaires were anonymous and time stamped.

When considering where students would benefit from training, more than 90% of supervisors agreed that time management was important, followed closely by project management, research methods and presentation skills. Training in ethics and environmental issues received low levels of support. When students were asked where they would benefit from training, the most popular activity was research methods, with 90% expressing an interest. This was followed closely by report writing and presentation skills. Time management and project management also attracted roughly 80% of students indicating a positive view on training.

When asked whether PDP would add value to the FYEP there was no strong opinion among academic supervisors. Adding a reflective account gained some support with supervisors, while maintaining log-books as part of good practice had overwhelming support. FYEP students were supportive of the use of PDP as part of the FYEP experience, with 80% agreeing that this would add value to the project. Reflective writing also received good support, with more than three-quarters of returns in agreement, and the maintenance of log-books as part of good practice was agreed by 90% of all students.

The project investigated the use of technology in the FYEP and, in particular, the employment of an e-portfolio application (FYP:SPA) developed for the PebblePAD package. The survey, in addressing supervisors' familiarity with technology, highlighted limited expertise in a number of the packages. While most supervisors are at least competent in the use of Blackboard, other applications such as the social networking tools Facebook and Ning and university-supported packages Elluminate and PebblePAD have very little exposure among supervisors, as underlined by the interviews. Technology usage amongst FYEP students illustrated a high level of expertise in the university's virtual learning environment (Blackboard), with 92% of students being at least competent. Of the other packages, 70% and 73% of students indicated at least competence in Facebook and Skype respectively. PebblePAD, the university's e-portfolio tool, was untried by 87% of returns, with similar lack of exposure being recorded for Elluminate and the social network package Ning.

The interviews also revealed the practice of scheduling meetings in groups to increase efficiency and create a peer pressure atmosphere to encourage progress.

From the results of the data gathering exercise, a pilot trial phase was devised and implemented halfway through the first semester of the 2011/12 session. A three-hour training session on PebblePAD, attended by 31 members of staff, was provided in September 2011. The pilot trial involved the adaptation of an existing PebblePAD application that had been developed for level 4 students by members of staff from the Centre for Education Development, namely the *Skills and Personal Reflective Activity* (SaPRA). The *Final Year Project: Skills and Personal Reflection Activity* application (FYP:SPA) was developed to conclude the project and was accessible to all FYEP students from a PebblePAD gateway. It was launched in Week 6 of Semester 1 during a dedicated hour-long seminar, attended by 33 students.

Upon initial access, students are asked to self-evaluate their competence on a scale of 1 to 5 under various activities clustered under six skill statements (*Academic Writing, Academic Reading, Communication and Presentation, Individual and Learning Strategies, Research,* and *Library and Referencing*). Resources within each skill set are used to inform students of freely available training opportunities based on internal training events or open educational resources available via the internet. As a student undertakes training and collects evidence, self-evaluation can be re-performed to demonstrate personal development and learning progression. The student has the option to share this development with their supervisor.

In summary, the use of e-portfolio tools to enhance the FYEP has been shown to be viable, with the launch of the FYP:SPA application towards the end of the project. There are, however, barriers to be overcome if such an approach is to be seen to be worthwhile and relevant to today's FYEP experience. The online questionnaires demonstrated students' readiness to incorporate PDP into the FYEP, but there was less enthusiasm from supervisors, as reinforced during interviews when concerns about increased assessment load, as well as the need for PDP at levels 4 and 5 as a precursor to the FYEP, were identified. The reasons for students' enthusiasm for PDP inclusion in the FYEP is less clear and additional investigation into their views on the relevance and value of embedding PDP within engineering curricula would, in this respect, be beneficial. The questionnaires illustrated a crucial lack of awareness of the capabilities of the university's e-portfolio tool (PebblePAD) among supervisors and students, while there was a clear difference in the use of the social media tool Facebook and internet communication tool Skype between supervisors (who had little experience) and students (many of whom considered themselves to be experts). A lack of exposure among supervisors and students to the potential benefits of e-portfolio tools needs to be addressed if such tools are to be integrated into the FYEP in the long term, while according to the literature disparity in the use of Facebook and Skype (two potentially useful FYEP applications) may not simply be due to the age difference between supervisor and student but also due to factors such as breadth of internet use and experience of using internet technologies.

While the project focused on FYEP students, the approach could equally be applied to other disciplines and, by raising awareness, the project provided the momentum to further deploy e-portfolios across all years of study.

In terms of further development, the FYP:SPA application provides the first step towards the development of a fully integrated e-portfolio tool that can be employed for PDP as part of the project process and there may be the opportunity to integrate the FYP:SPA application and the level 4 induction tool SaPRA, along with an application specifically developed for level 5 training, to provide a fully integrated level 4 to 6 PDP package. There is also a natural extension of the FYP:SPA application to postgraduate taught programmes and research activities, with suitable modifications to reflect the skills needs of these particular cohorts.

The key to future development is to illustrate the added value that such an approach can provide for supervisors and students alike. The launch of the FYP:SPA application halfway through the first semester, shortly after students had received confirmation of their projects, proved to be too late in the project and too early in the FYEP process for students and supervisors to provide informed assessments of the value of the developed application. Further work in determining students' and supervisors' practical experiences of the FYP:SPA application would be required to help further develop and refine the application's capabilities.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/e-portfolio_tool.pdf**

trans:it engineering

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A synopsis by the editorial team

Abstract

The overall aim of trans:it engineering is to support the transition of engineering students from further to higher education and thereby increase the learning effectiveness and long term success of learners entering higher education from vocational courses such as those offered through BTEC. Generic trans:it material developed during 2009/10 has now been supplemented by engineering-specific material. In common with the original trans:it, it is available both as a web-based and a paper-based version. The website **www.transit.ac.uk** contains all the student support and tutor guidance material.

Following a staff and student consultation process, six topics were identified as areas of particular importance to students making the FE to HE transition. Support materials were produced around these themes, designed for use during tutorial sessions within the FE context. For each of the six topics listed above there is tutor support content in addition to the student content. It is also possible for the materials to be used by students in HE and independently.

A seventh section was produced during 2010/11 by a similar staff-student consultation process, to cover areas specific to engineering. Future plans include developing trans:it science in the same way.

trans:it can be adopted wholesale by other institutions, used selectively or modified to meet specific requirements.

Keywords: transition, progression, learning materials, vocational progression, support, guidance materials

The project

Bradford pays extensive attention to student support, and a number of resources and materials are available across the institution, particularly through Learner Support Services (LSS)

The starting point for the project was an assessed module (The Effective Learner) offered through the School of Lifelong Education and Development (SLED) and learner support material previously produced by the School of Management.

The trans:it activity based at the University of Bradford arose in response to issues surrounding the transition of students from further to higher education (including diversity of course and qualification background and wider variety of modes of study or assessment). With the support of the former West Yorkshire Lifelong Learning Network (WYLLN), the University of Bradford and partners in higher education (HE) and further education (FE) produced an interactive and accessible suite of generic support tools (booklets and website) in July 2010 for use with FE learners, enabling them to recognise their strengths and address their development needs in preparation for learning in higher education. Referring to its themes of transition and support through IT, the material was called trans:it.

The themes and content of trans:it were identified during three consultation sessions involving staff from both sectors, FE students intending to progress to HE courses and students currently studying in HE who had made that transition. As a result of this consultation process, six topics were identified, covering issues of particular importance faced by students moving into HE courses from vocationally based provision in FE and organised as follows:

1. You and Higher Education
2. The Independent Learner
3. Time Management
4. Managing Information
5. Writing for Higher Education
6. Group Work

These six sections make up the trans:it package now being used in HE and FE institutions not only across West Yorkshire, but also much further afield. The material was principally intended to be used in a tutorial context; alongside the student content in each of the six sections there is additional guidance material for tutors. However, it was designed so that it could be used independently by individual students and this flexibility led to the widespread uptake of trans:it material across the UK and indeed across the globe.

The development began by carrying out two formal literature investigations, firstly considering specific differences between the two levels of study and secondly how existing schemes had been developed elsewhere specifically to support the FE/HE transition.

In producing the original trans:it, we considered only generic issues across the range of subject areas. On receipt of the HE STEM programme funding we revisited the model and an additional section designated trans:it engineering was produced in response to specific needs.

At the heart of the development programme was a set of staff/student consultations. The approach during 2009/10 consisted of:

1. an initial consultation with FE and HE staff to discuss the current difficulties observed in students progressing from FE into HE courses either in higher education institutions (HEIs) or by continuation within the further education college (FEC)
2. a second staff-only meeting to finalise the list of topics
3. a consultation with the above staff and a sample of FE students intending to move to HE courses and HE students who had come from the FE sector having followed vocationally-based courses such as the BTEC National Diploma
4. the commissioning of a specialist writer to capture the views of the staff and students and organise them into a draft support programme
5. a final consultation with the staff and students to survey the material produced and advise on potential improvements
6. the commissioning of a web author to design and execute web pages based on the written output, bearing in mind the need for interactivity and accessibility
7. a regional launch for local colleges and universities.

We made use of the Wikispaces facility to keep staff and students in touch with emerging material and encouraged them to feed back at any stage between meetings. In practice, very little feedback was obtained through this mechanism, compared with the focus group meetings.

During 2010/11, we used support from The Royal Academy of Engineering/National HE STEM Programme to apply the above methodology specifically to engineering subject areas. We considered the six existing sections in the light of issues identified by the consultation process, identified areas of additional engineering-specific support and combined them, creating a new seventh section: Engineering.

Within the engineering section there are eight units based on topics of particular use to those moving on to engineering-based HE courses. These are:

1. The Engineering Profession
2. Maths for Engineers
3. Underpinning Science
4. SI and Imperial Units and Correct Usage
5. Materials and their Properties
6. Project Management
7. Control Systems
8. Engineering Extras.

In common with all trans:it material, there are guidance notes for tutors and students for each unit. These are available in printed form or online at **www.transit.ac.uk.**

As of July 2010, the generic trans:it material had been in use for one year, and the current sustainability plan includes evaluation using feedback questionnaires from all user institutions. Initial informal feedback from staff and student users has been very positive:

To summarise, from the outset we felt that the key to success for trans:it was the full involvement of staff and students. Three consultation events were at the heart of the project. This approach was effective and beneficial in that it clearly identified additional areas of support required to make the transition from further to higher education across engineering subjects from the perspective of teachers and learners.

We had difficulty getting the same group of people together for all three meetings (considered important for continuity and cohesion). The process was managed by offering a small financial inducement to student participants, with a bonus for attendance at all three events.

The key to success is finding the right person to produce the material. As we moved from generic thinking to engineering-specific thinking, additional demands were made on the writer of the material who needed to combine subject expertise with a balance of expertise and humility and the ability to combine a knowledgeable and authoritative perspective with a willingness to make amendments based on student feedback.

Other institutions can introduce trans:it at several levels. Firstly, students can use the material as and when they need it; it is openly available and can be used in a stand-alone manner. Secondly, colleges and universities can adopt the material as it is, either in a guided context such as in tutorial or study support sessions, or by cross-reference through their websites and learner support activities. Thirdly, colleges and universities can adapt the material to their own needs, actively selecting relevant parts, modifying others and/or inserting their own examples or features. Finally, institutions may wish to reproduce the whole process of consultation and develop their own version of the support material, perhaps for an entirely new subject area. Within the constraints of available resources, project staff are more than willing to assist with any of these levels of adopting the material or extending its range.

In terms of further development, there is limited sustainability funding from WYLLN to continue to support trans:it, of which the engineering section is now an integral part. There will be additional support during 2011/12 from the National HE STEM Programme to develop trans:it science. This involves a similar staff-student consultation process and has an emphasis on transition from BTEC science courses to HE science courses. Two new features include transition from school as well as college and inclusion of institutions from a wider geographical region.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/transit_engineering.pdf**

Uncovering threshold concepts in first year engineering courses and implications for curriculum design

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A synopsis by the editorial team

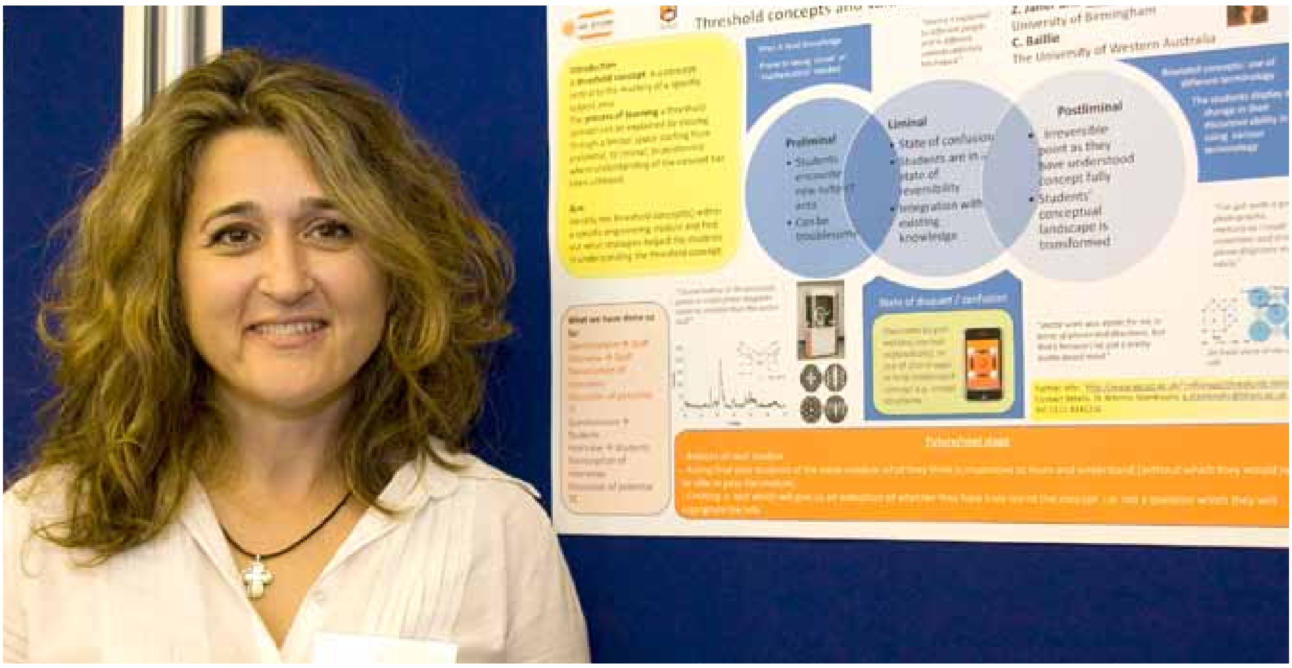
Abstract

The idea of threshold concepts was developed from a UK national project which focused on student learning in different disciplinary areas. Certain concepts were identified, held to be central to the discipline, which would open up required systems and ways of thinking and yet were troublesome for students. Not only can threshold concept theory help in focusing students' and teachers' attention on the tricky "stuck places" in a subject, it can also act as a powerful curriculum development tool. This project investigated level 4 student experiences of engineering and explored how students related their courses to learning. The outcomes of the project include recommendations about how curriculum design initiatives can enable all students in the first year of their studies to navigate through these thresholds as they progress further through their studies towards becoming an engineer.

Keywords: **threshold concepts, curriculum design, engineering, social responsibility**

Although we are living in an exciting period of pedagogic innovation during which approaches to teaching and learning have improved dramatically, students still meet concepts that they find troublesome. An example can be found in the use of maths in materials engineering teaching. Often students complain that complicated equations are difficult to remember or understand. As a consequence a lot of materials engineering modules, especially at level 4, are taught in a descriptive manner. A particular area is the *structure-properties-applications* relationship. Even though basic mathematical equations are not used, the students still cannot grasp the implication of the above relationship. Consequently we have chosen to examine this area in the context of the *threshold concept* framework with the aim of helping students to understand the importance of learning certain key aspects of their subject in spite of the difficulty, become more confident and develop their identity as professionals.

The idea of threshold concepts developed from a UK national project which focused on student learning in different disciplinary areas. Certain concepts, held to be central to the discipline, which would open up required



systems and ways of thinking and yet were troublesome for students, were identified. Three seminal edited books have been published which together traverse a wide range of disciplinary contexts and provide an international perspective on threshold concept theory. It has been suggested that not only can threshold concept theory help in focusing students' and teachers' attention on troublesome areas of a subject; it can also act as a powerful curriculum development tool. There is a growing body of threshold concept research in electrical and electronic engineering and computer science and some significant recent work in chemical, civil and mechanical engineering; however, it is hard to find published work on threshold concepts in materials engineering, with the exception of one recent paper where attempts are made to identify threshold concepts in nanotechnology using curriculum mapping. Current methodologies to identify threshold concepts mainly include the use of interviews of students and lecturers and evaluation of questionnaires. Recently, however, the use of concept mapping conducted at the University of Oxford during a collaborative project with the University of Birmingham proved very useful not only for the identification of threshold concepts, but also for the evaluation and study of the learning processes involved. In this project we used both questionnaires and concept mapping approaches.

The project reported here aimed to identify and compare possible threshold concepts in level 4 engineering

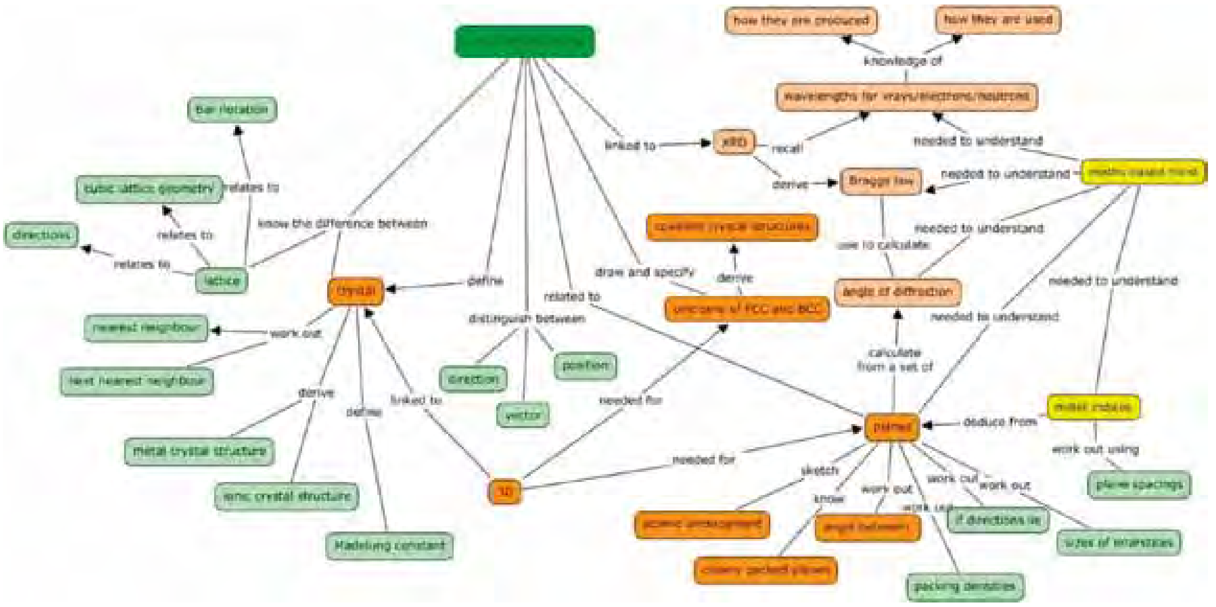


Figure 1. A concept map of crystallography

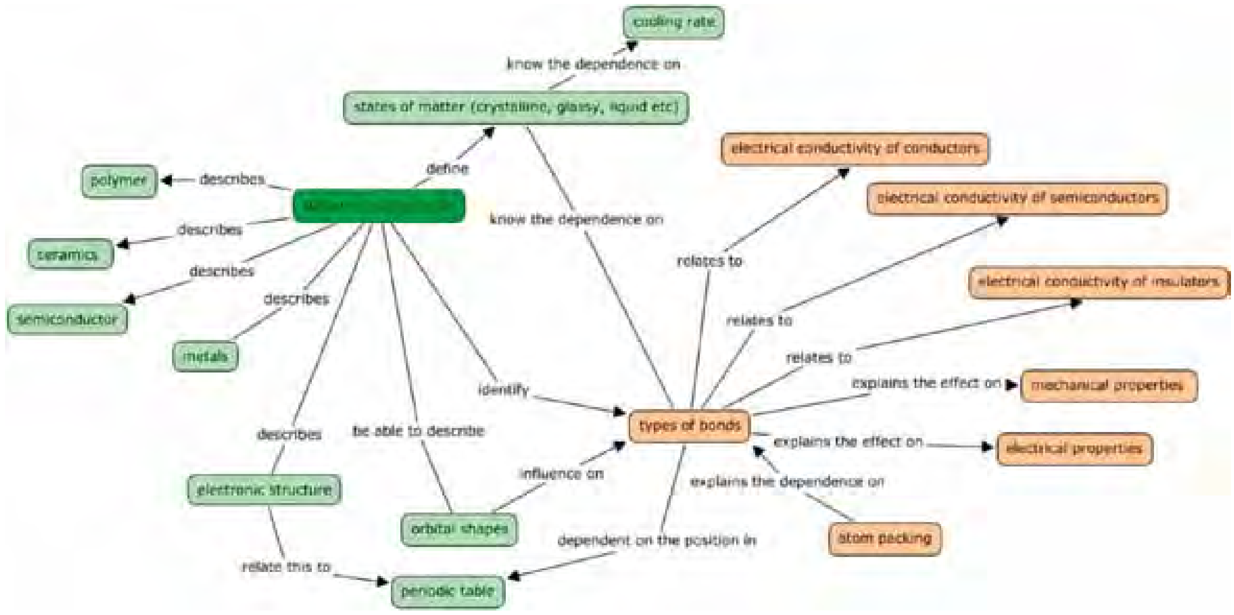


Figure 2. The concept of atomic structure

courses in metallurgy and materials at the University of Birmingham, evaluate the current course design in light of the identified threshold concepts and make recommendations for the re-design of courses where appropriate to support students' learning.

It was initially considered that a simple questionnaire for staff and students and a face-to-face interview would be the best way to start identifying potential thresholds. Questions were designed to find out what staff and students believed the key areas of crystallography/phase diagrams to be and which areas they found to be the most troublesome. Staff were asked whether they thought students' responses to the questions would correlate with their own and students were asked what they thought about the impact of these key and troublesome areas on their future careers.

We eventually came to the conclusion that we were able to identify troublesome areas but not necessarily any threshold concepts from these questionnaires. The questionnaires were extremely helpful in uncovering the thoughts of staff and students, understanding their relationship, what they think about the subject and what they feel about the subject. The process of learning, however, could not be unveiled from the answers. We therefore decided to use the idea of concept mapping to connect and relate the answers within the context of the subject. This was helpful in order to reach an understanding of how the module under study was developed, what areas were emphasised in teaching and what areas were the troublesome ones and why.

Both lecturers were interviewed and 50 students were interviewed in focus groups of five. The interviews were transcribed and, together with the answers to the

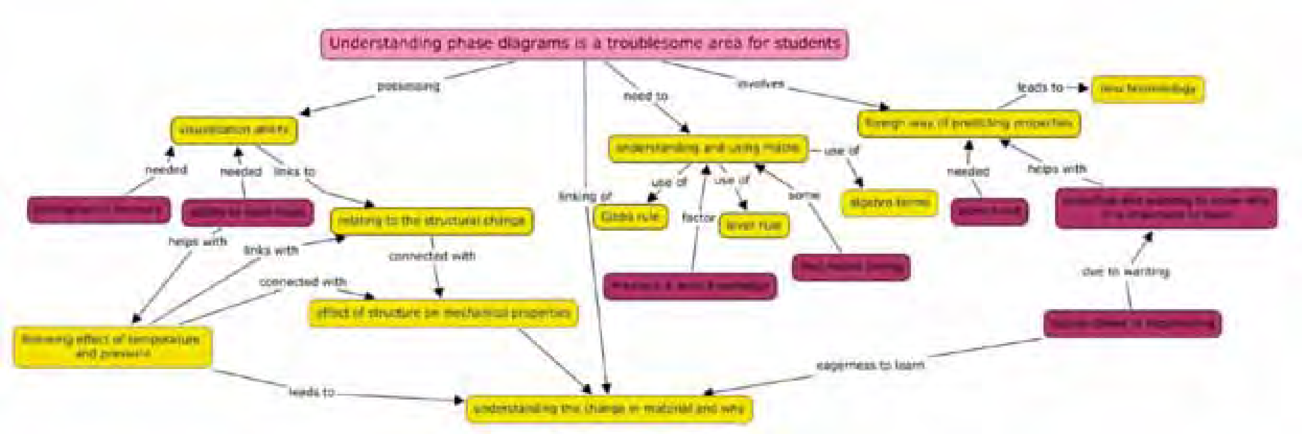


Figure 3. Phase diagrams concept map 1

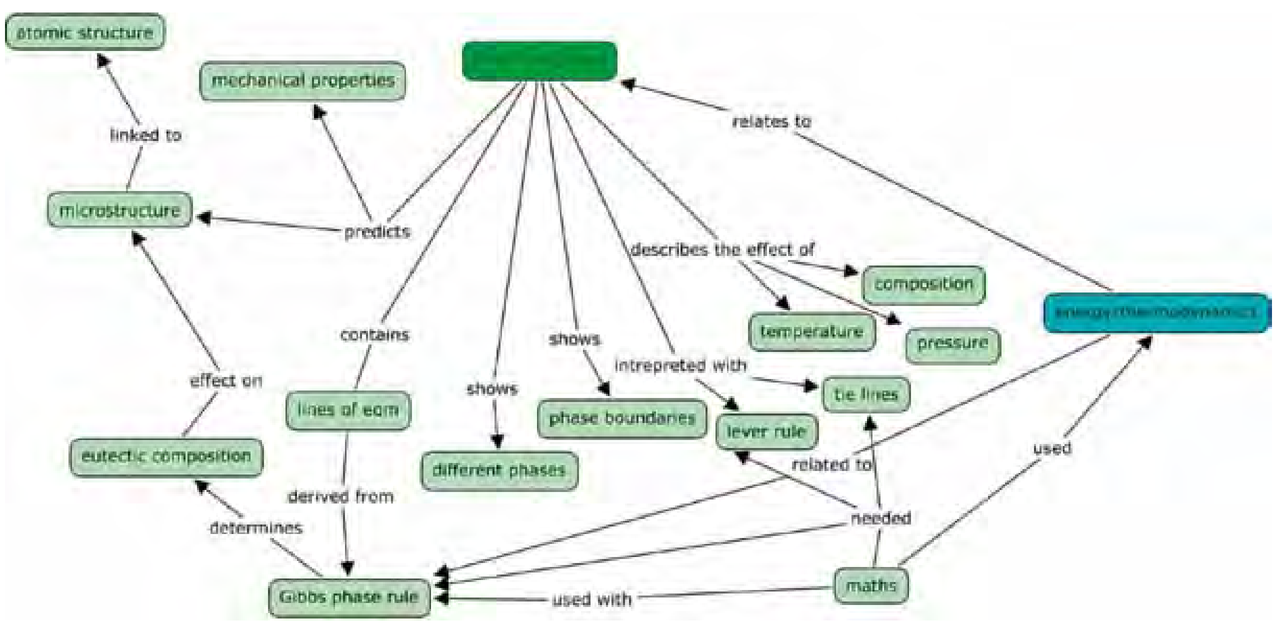


Figure 4. Phase diagrams concept map 2

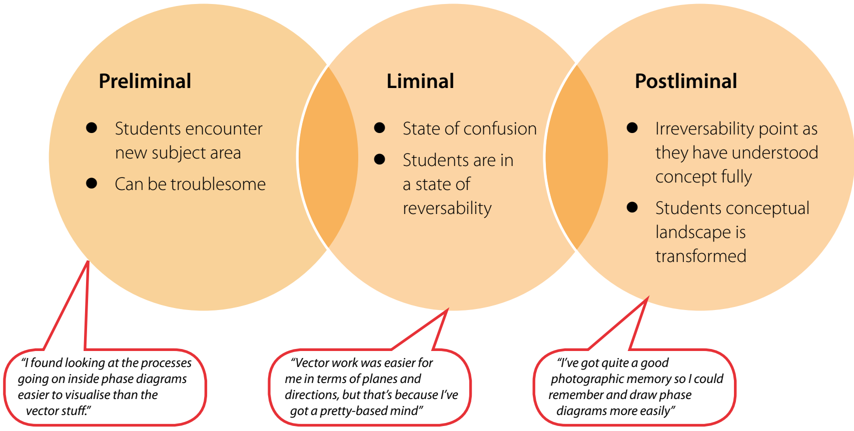


Figure 5. The learning process and how it was understood from the interviews with students

questionnaires, the responses were used to develop concept maps. The concept maps, prepared in Cmap Tools, took phrases or words from the coded transcripts and explored the relationships between them by linking them with arrows and linking phrases. This type of analysis is highly subjective but has been used in other research to help to organise and structure knowledge with small units of interacting concept and propositional frameworks.

Crystallography concept map 1

Figure 1 explores the connection and relationship between words that all together form the meaning of crystallography. The colours do not have a particular meaning but they have been used to facilitate or group related areas. It was considered that points that link large areas or are more populated might be troublesome areas, as more concept units are necessary to the learning of the specific area. We can see that 3D visualisation, for example, connects the three larger areas in the map. Also, concepts such as crystal, Bragg's Law, XRD and planes (crystallographic) are central and understanding of them could be important to understanding crystallography.

Crystallography concept map 2

Figure 2 shows a concept map of atomic structure that follows on from the "atomic arrangement" in Figure 1. Similarly, in this map it was deemed important to analyse the concept of atomic structure that also seems to be central to crystallography. Here concepts such as types of bonds and the periodic table are also central.

Phase diagrams concept map 1

From the student interviews, an area that was identified as troublesome was "understanding phase diagrams". In this map, shown in Figure 3, we tried to analyse the learning process from information that the students themselves gave. It was impressive to see that a lot of the problems were caused by a lack of basic maths knowledge, lack of familiarity with new terminology and visualisation ability (including memory).

Phase diagrams concept map 2

In this map, shown in Figure 4, it is clear that concepts such as thermodynamics, Gibbs phase rule and microstructure are important in order to read and understand a phase diagram.

It was evident that phase diagrams, although having been identified as a troublesome area by the students, are the tools with which students can potentially predict and identify phases in materials. A concept such as a phase diagram cannot be a threshold concept. On the contrary, there are areas (such as specific terminology behind the tool) that students need to have understood prior to the use of phase diagrams, for example, what is meant by 'a eutectic alloy' is or what phase separation is. In order to identify these areas a more detailed questionnaire should have been designed, although it should be obvious to the lecturer that they must identify the knowledge required prior to using phase diagrams as a tool by exploring the capability of their students and then adapting the level of background knowledge that needs to be taught. Using a method like concept mapping, it is possible to build up the level of knowledge and identify the points that need to be understood before trying to learn a troublesome area or concept. It is therefore understood that this "prerequisite knowledge" should satisfy the main characteristics of a threshold concept and involve a learning process that could be represented by the schematic diagram in Figure 5.

As a part of a larger consortium that explored different areas of engineering education, this project has helped to develop a methodology, based on knowledge concept maps, of identifying engineering threshold concepts. It is understood that the threshold concepts identified in this project will lead to an improvement of current module design by incorporating elements that can reinforce background knowledge, leading to a better understanding of troublesome areas that are not themselves threshold concepts (such as phase diagrams).

Some of the ideas that came out of this project were well received not only by some of the members of staff at the University of Birmingham, but also by the Director of Education who is very keen to further explore engineering threshold concepts. We are planning to submit a proposal to the university for internal funding to continue the work and expand our research to other disciplines, with the aim of applying threshold concept theory in the schools across the College of Engineering.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/uncovering_threshold_values.pdf**

The Nuclear Island

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A synopsis by the editorial team

Abstract

The *Nuclear Island* project established partnerships between industry stakeholders and higher and further education providers to develop an outline agreement on the critical future workforce needs identified in the Cogent report *Next Generation: Skills for New Build Nuclear* (2010).

Building on established good working practice identified in The Royal Academy of Engineering reports *Engineering Graduates for Industry* (2010) and *Nuclear Lessons Learned* (2011), a partnership led by Cogent Sector Skills Council and Imperial College London in association with Constructionarium Ltd, Engineering Construction Industry Training Board (ECITB), the National Skills Academy Nuclear and Construction Skills facilitated three employer and education provider events at The Royal Academy of Engineering which focused on addressing specific requirements to determine, develop and establish a simulated problem-based learning experience for undergraduate civil engineering students for nuclear new build based on the proven "Constructionarium" initiative.

The outcomes of these events provided a framework for the additional curricular material, industry behaviours and delivery methods necessary to meet the requirements of industry. Student numbers and costs of provision to all parties were also determined, with an emphasis on developing a sustainable and transferable activity.

The programme encouraged sector engagement in higher education activities and has been helping to deliver world-class employable graduates in strategic UK sectors since June 2011.

Keywords: employer engagement, HE curriculum, nuclear industries, workforce upskilling

One of the UK's strategic growth areas is its nuclear new build programme, where Government and employers have recently identified critical skills for the supply of the future workforce. The Nuclear Island project aimed to increase the number of graduates with the skills required to meet the nuclear new build need and establish the learning outcomes and delivery method required to increase the exposure of students, lecturers and employers to nuclear new build environments that currently do not exist in the UK.

Sector-based approaches to new areas of growth are a key priority for the UK Government and collaborative approaches to sector-based programme development can be extremely beneficial, providing evidence-based approaches to the collection and sharing of information and lessons learned from the implementation and delivery of employer-informed curricula and a national approach to pan-STEM curriculum delivery which supports academics and employers through packages of learning. Bringing together HE with further education (FE) colleges, stakeholders and employers reduced risk to all parties by coordinating a sector-based activity which addressed the learning, development, delivery and sustainability of this and future programmes.

Through the transfer of established best practice in civil engineering programmes across the higher education (HE) sector in England and Wales and international experiences of nuclear new build to this new up-and-coming sector, open discussion was facilitated between industry and academia to determine solutions which could provide future graduates with the skills and experience required for nuclear new build. With employer attention focused on the skills needs of the future, their input to the programme was essential in ensuring that the curriculum, nuclear behaviours and ownership of the developments were secured. Employer fora were also used to discuss the strategic and financial issues relating to the delivery of the learning model, as well as wider opportunities to engage with HE and FE staff and students.

The project encouraged coordinated UK-wide employer engagement in HEI activity, aiding delivery of world-class employable graduates into strategic UK sectors. This also provided an opportunity to identify and support packages aimed at developing cross-STEM CPD for both employers and lecturers to aid delivery, increase employer engagement and provide information, advice and guidance for their participation in sector-based projects. Employers recognised that progression into HE could be established through the Nuclear Island programme and requested that universities work more closely with FE colleges, enabling careers information and guidance to be developed cohesively. In addition, employers' existing outreach mechanisms can also be widened through this programme, linking schools, colleges and HE together to support a sector approach to engagement around careers information.

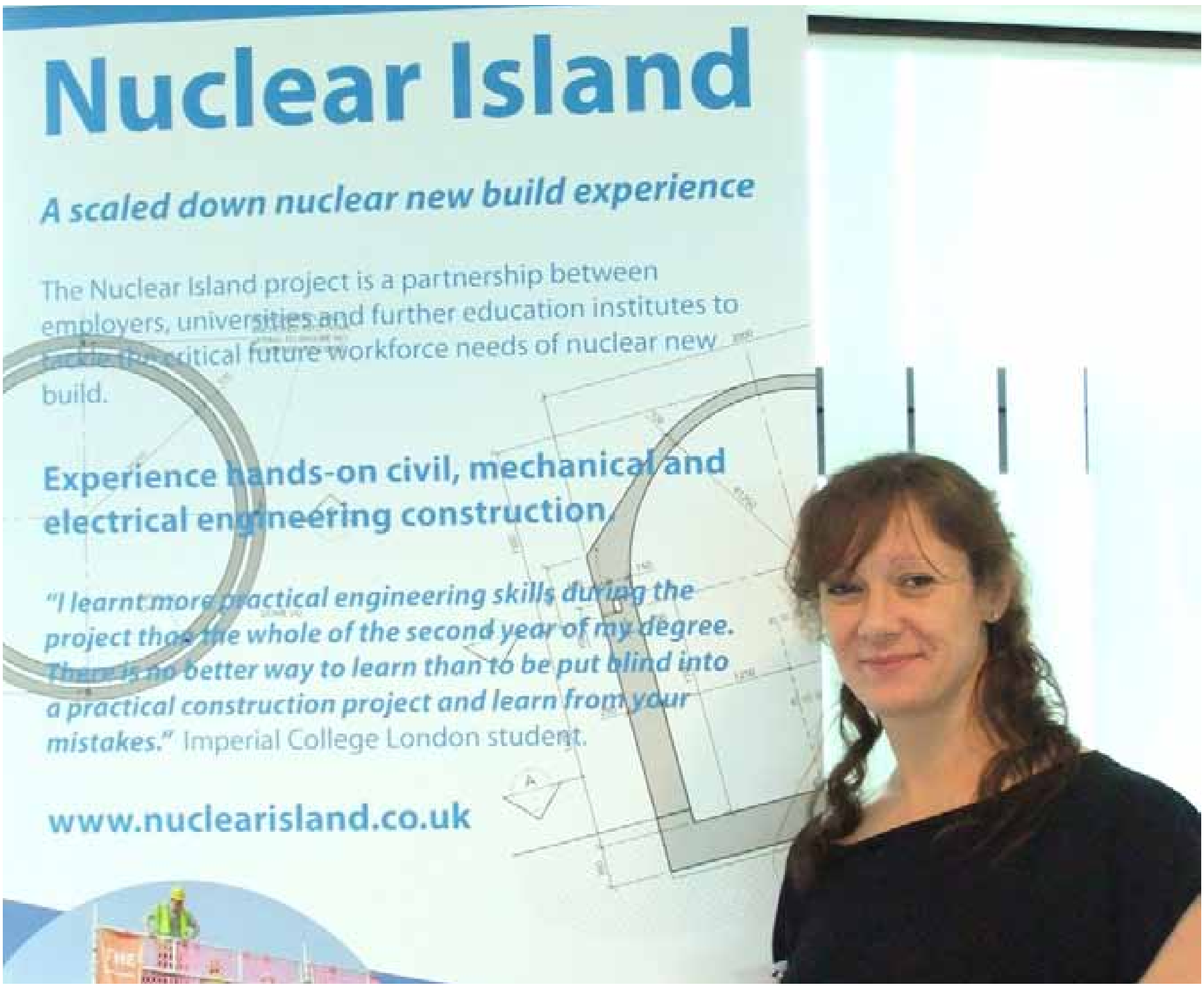
This programme aimed to be industry recognised and championed, enhancing learning outcomes not only for university students, but for lecturers and employers alike – all parties benefited from this consortium approach. Through this programme, the skills needs for nuclear new build are being tackled and delivery eased by attraction of people into an industry which recognises the skills developed through interaction with the programme.

The first phase of the Nuclear Island programme was to bring together industry and education providers to coordinate and deliver solutions that would meet the graduate skills needs for nuclear new build. Through active partnership between Imperial College London, Cogent Sector Skills Council and Constructionarium Ltd, a programme of activity to approach this research phase was coordinated in order to establish the learning outcomes, delivery method and approach for the nuclear and civil engineering sectors to aid the future development of an undergraduate package that could be used and transferred to other universities engaged in the existing Constructionarium site.

Through the project team, three events were organised and operated as Open Fora, allowing all stakeholders to freely discuss the development of the Constructionarium project in the nuclear new build sector. Specific topics were agreed for discussion in break-out sessions facilitated by speakers from industry and education, in order to establish feedback and evidence to take the project forward.

Event invitees included:

- Employers from the nuclear and civil engineering sectors (and their supply chain) in order to achieve a coordinated approach and input to specific nuclear new build issues (23 in total, including Balfour Beatty VINCI, EDF Energy and Rolls Royce, amongst others)



- HEIs currently engaged in the Constructionarium project, in addition to those providers offering nuclear specific and civil engineering courses
- A number of FE colleges, to encourage and establish links to the programme.

The first event was specifically for employers and the second for education providers. This approach was taken as it enabled clear messages to be delivered to each audience and allowed the priority issues to be discussed without prejudice. The third event acted as a joint meeting where clear arguments and concerns could be addressed and discussed openly. The topics discussed through facilitated workshops included:

- Detailed curriculum content and delivery modes
- Costs to establish and operate the Nuclear Island
- Student numbers
- Sustainability options
- Opportunities for FE engagement
- Development of CPD for academic and industry employees.

All information regarding the project and the events was coordinated by Cogent SSC. The programme was well publicised through a dedicated Communications and Marketing Team and a steady flow of information was maintained through press releases and electronic media (including a dedicated web portal for free access to key project information), ensuring continued engagement.

Through the facilitated workshops, evidence was gathered and reports written by the project team to establish the critical issues for the development of the future nuclear new build programme and the following learning outcomes were established.

Assessment and evaluation of the project were measured in terms of engagement of the project team with employers, stakeholders and other educational institutions. At each of the three events, informal feedback and support was requested to inform priorities and future direction. Feedback forms were used at the first two events to engage and monitor event organisation and additional feedback.

Measures of success included a count of employers, HE and FE institutions and other stakeholders engaging with the project and attending the events, their commitment to the programme through continued engagement and their subsequent engagement in the follow-on programme. In total, 16 universities and FE colleges, 23 employers and 11 key stakeholders attended the three events. In terms of achieving project outcomes, the events facilitated successful interaction of education providers with industry and key stakeholders, enabling learning outcomes to be determined, delivery methods to be challenged and solutions determined, costs of development and operation openly discussed and

supported, engagement with the FE sector achieved and the wider issues regarding development of supporting materials for both industry and academic CPD to be discussed. The number of delegates attending the events could have been increased had the project not been restricted in terms of timescale and availability of dates at the location of events. However, this has not detracted from the additional engagement with employers and providers through other media, including email and website traffic, and through additional face to face meetings and teleconference calls with the project leads.

Establishment of deliverables was also a marker for project assessment and evaluation, ensuring progression. These included clear presentation of development, delivery and operational costs for the programme, employer-informed curriculum and learning outcomes, assessment of potential student numbers and options for sustainability, including CPD for academic and industry employees.

The value proposition was well received by the civil engineering community. However, the potential to expand the existing Constructionarium concept beyond the civil engineering boundaries was challenged. Employers welcomed the programme, but wished for expansion of the curriculum into other areas of STEM, particularly mechanical and electrical engineering. It was agreed that some issues were beyond the scope of the existing funded programme of activity and that there needed to be a mechanism to take forward suggestions with employers and education

Nuclear Island learning outcomes

A Nuclear Island Constructionarium project aims to increase the experience of civil engineering related to the nuclear industry. It is perceived that such a project should not be limited to civil engineering undergraduates but should become available throughout the skills pyramid of school and FE students, right through to postgraduate students and possibly those in the workplace in need of skills improvement. The existing Constructionarium initiative includes a range of objectives for civil engineering undergraduates. These include:

- "Hands-on" experience of scale civil engineering projects
- General construction site experience
- General health and safety awareness
- Project management awareness
- Personnel management practice
- Communication skills practice
- Identification with engineering.

Nuclear construction projects are subject to rigorous safety justification to provide assurance of long term safety of the facility, workforce and general public. As such, specific learning outcomes for a Nuclear Island Constructionarium project should include:

- Awareness of nuclear safety culture and nuclear safety practices
- Awareness of the need for rigorous quality assurance (QA) processes and quality control measures
- Awareness of nuclear industry career opportunities.

To enable these objectives to be met, the existing Constructionarium project brief was amended to include the roles of:

- *Quality Assurance Officer* (QAO). This should be a student member acting as the Contractor QA Officer to provide assurance with the project brief requirements
- *Site Operator's Compliance Officer*. A staff member acting as the operator's overseer of nuclear safety and QA requirements and compliance with Nuclear Site Licence Conditions. The student QAO reports any deficiencies to the Compliance Officer who provides feedback on the impact of the deficiency on the safety justification and any necessary rectification work or immediate or future inspection regimes
- *Her Majesty's Nuclear Inspector*. A staff member acting as the site Nuclear Inspector, conducting irregular inspections of the on-site activity and checking for general and nuclear health and safety issues.

providers in order to aid delivery of a cross-STEM model which would address the community as a whole.

All expected outcomes for the programme have been met, with additional benefits gained from engagement with Government bodies (including the Department for Business, Innovation and Skills and the Department of Energy and Climate Change, where ministerial support has been expressed for the programme) and, unexpectedly, students.

External factors, including the events at Fukushima Dai-ichi Nuclear Power Plant (subsequent to the earthquake and tsunami hitting the Tōhoku region of Japan in March 2011) also affected the impact of the programme. Specifically:

- Interest in the future of UK nuclear new build was raised: students were engaged and began discussing the technical and societal effects of nuclear power operations in lectures at Imperial College London, providing a real life element to the safety and build specifications required
- The events at Fukushima prompted the Government to commission the Weightman Report to determine the future of new nuclear build in the UK. This postponed employer financial commitment to the programme until the report was published and there was Government agreement to continue with the proposed 16GWe nuclear new build programme
- Engagement with the aspects of safety and build compliance have been highlighted as critical factors for nuclear new build: roles and responsibilities are currently under review, and future programme developments will incorporate recommendations from the Weightman Report

- The events also raised awareness of this particular programme to senior Government Ministers, including the Minster for Higher Education.

In summary, the Nuclear Island project has established a network of HE and FE providers, employers and stakeholders committed to the development, establishment and delivery of the Nuclear Island concept. During this initial research phase, the following outcomes have been achieved:

1. A broad consensus of the knowledge, skills and competencies for civil engineering practices in nuclear new build
2. An agreed overview of potential mechanisms for delivery based on the existing Constructionarium concept
3. An overview of a paradigm to include the disciplines of nuclear physics and mechanical, electrical and chemical engineering, supported by the required underpinning engineering and financial mathematics
4. A core group of employers, HE and FE institutions committed to a follow-on funding programme which has helped to develop and pilot a civil engineering programme from June 2011–June 2012
5. Commitment from other employers and education providers has been secured in order to develop a wider STEM programme based on the Nuclear Island pilot programme.

Full details of the event outcomes can be found through the Nuclear Island website (**http://www.cogent-ssc.com/Higher_level_skills/ni_index.php**).

The project partnership has facilitated a sectorial approach to communication, interaction and delivery, more specifically:

- National and regional HE partners have been attracted to the programme, bringing their subject specialities and expertise to the fore to help produce a curriculum that can be delivered to students and lecturers across their STEM footprint, maximise local employer engagement and work alongside FE partners
- Professional bodies, led by The Royal Academy of Engineering, have advised and embedded good working practice around curriculum development and delivery
- The employer engagement team, comprising Cogent, Constructionarium, Construction Skills and ECITB, has brought together national employer partnerships to aid design and delivery of Nuclear Island and the support packages for its future use
- Other stakeholders, including the National Skills Academy Nuclear, the National Construction College, trade organisations and other professional bodies, will be utilised to inform and maximise engagement of employers with providers, and establish professional recognition of the scheme in the future.

Additional benefits have originated from the close working relationship and direct engagement of the project team members to increase facilitation and discussion with Government, industry and students.

This programme has begun to address the immediate to long-term skills requirements of UK nuclear new build, develop a curriculum based on international experiences of nuclear new build and embed the principles of employer engagement in HE curricular development identified in The Royal Academy of Engineering report, *Engineering Graduates for Industry* (2010).

Through active partnership with the professional bodies already engaged in the National HE STEM Programme, accreditation of this undergraduate programme is currently being considered.

Based on the findings of the Nuclear Island project, further development of the pilot phase programme was undertaken from June 2011 to June 2012, funded by the National HE STEM Programme and employers. This shared responsibility, risk and facilities and established industry champions who have taken on an active role to encourage wider industry engagement and enhance the student experience, inform curriculum development for learners, academics and other employers at a time where there is less reliance on public funding. In this follow-on project, the "Building the Nuclear Island" team developed a "Plug and Play Programme" that was led through a consortium comprising Imperial College London, Constructionarium and Cogent Sector Skills Council, involving expertise from industry, professional bodies and HE and FE institutions across England and Wales. This follow-on programme piloted a nationally available curriculum package based on a nuclear core reactor design enhanced by employer input (both in-kind and financial) to ensure that students and education providers across England and Wales are supported in their learning. This pilot also provided a route to developing a support package for academic staff and clarified best practice delivery mechanisms for the sector.

The full case study and literature references can be found at:
www.hestem.ac.uk/sites/default/files/nuclear_island.pdf

Integrated work-based learning in clinical engineering education

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A synopsis by the editorial team

Abstract

Traditionally, engineering higher education has not made use of formal work-based learning (WBL). Where WBL has occurred it has been in the context of a sandwich placement year and there has been limited integration with the taught part of the course. This project aimed to develop credit-bearing WBL for a series of placements integrated into each stage of a clinical engineering degree course. The programme is vocational, focused on healthcare science careers within the NHS and requires close partnerships with hospitals. From this project we hoped to establish an integrated WBL model that could be applied to the wider engineering sector.

Keywords: work-based learning, innovative curriculum development, employer engagement

The School of Engineering, Design and Technology (SoEDT) at the University of Bradford was the first in the UK to offer a Medical Engineering BEng and has been developing programmes for engineering and scientific hospital staff since 2001, with the launch of the first full-time Clinical Technology BSc in 2004. The Department of Health *Modernising Scientific Careers* (MSC) initiative made the integration of WBL in such programmes mandatory. Bradford was one of the few higher education institutions (HEIs) to secure additional student numbers for the new healthcare science programmes and we are the only HEI to deliver the new format clinical engineering course in the current academic year. This means that we are part of a small group of HEIs developing healthcare science WBL and the only one developing clinical engineering WBL. While SoEDT has a long history of industrial placements, and more recently WBL, we have not delivered programmes with mentor-led credit-bearing training before.

Although integrated credit-bearing WBL is unusual in engineering, use can be made of the experience elsewhere. This model of learning is very common in the health sector, where the combination of knowledge and understanding, subject-specific skills and professional skills are often seen as essential to an undergraduate degree. While the same could be said of engineering, the approach to education and training tends to be very different. There is also considerable experience in the further education sector and in part-time providers such as the Open University.

The Department of Health intends that successful completion of an approved healthcare science degree with integrated credit-bearing placements will be a requirement for all NHS employees in science and engineering practitioner roles and that this will form the basis of future regulation. This project therefore had the potential to shape education and training across the profession.

The project aimed to develop credit-bearing WBL as an integral part of full-time healthcare science (clinical engineering) BSc programmes and to use this as a model for the wider use of WBL in engineering. The objectives were to:

- in collaboration with employers, develop training materials and assessment tools that meet academic and employer requirements
- develop administrative systems for the management and support of student training placements, including mentor training
- develop training programmes for workplace mentors
- apply the principles and systems developed to other engineering programmes across SoEDT
- share experience of developing these new vocational courses (clinical engineering WBL in particular) with the wider HEI sector.

On successful completion of the project, it was planned that the outcomes would:

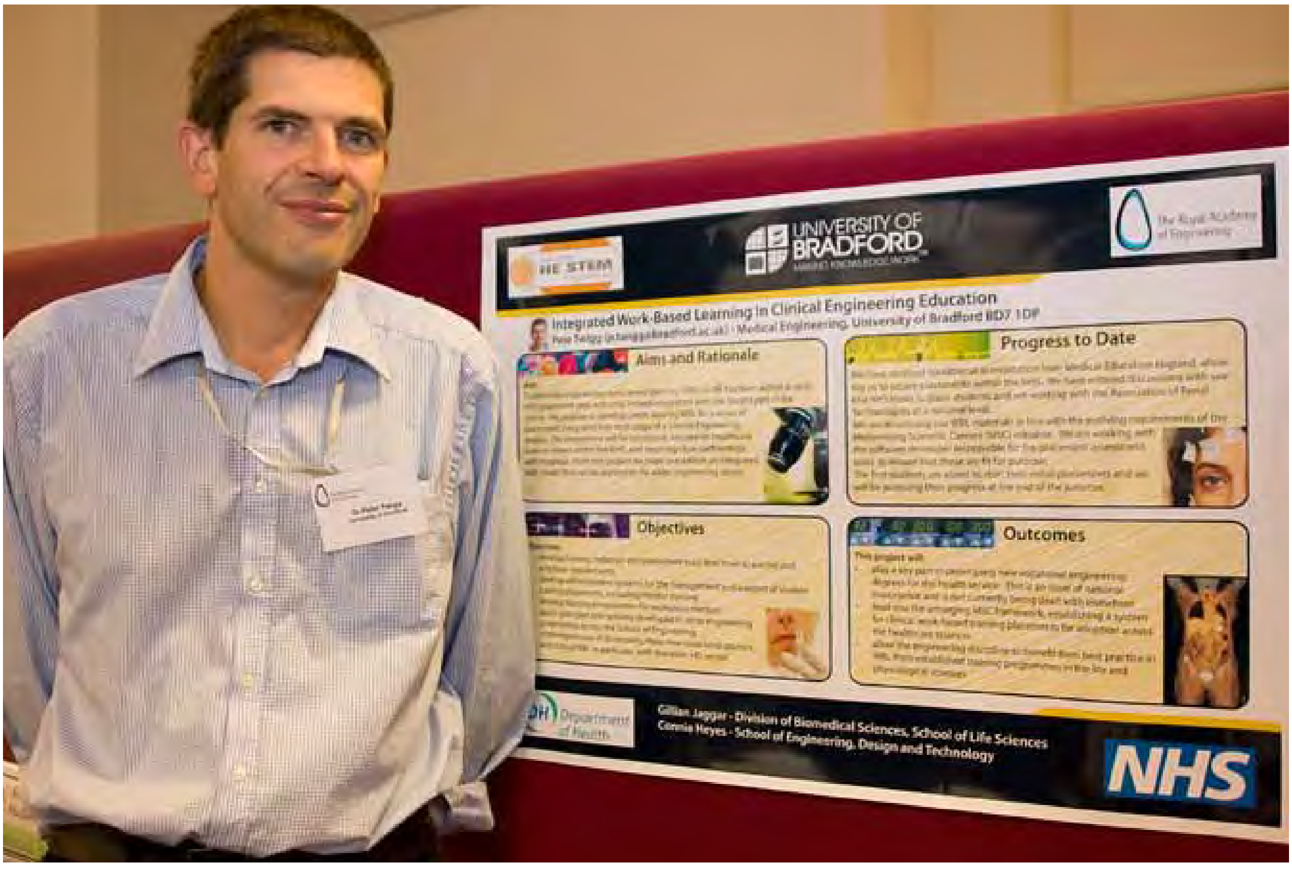
- play a key part in developing new vocational engineering degrees for the health service, an issue of national importance which is not currently being dealt with elsewhere
- feed into the emerging MSC framework, establishing a system for clinical engineering work-based training placements for adoption across the healthcare sciences
- allow the engineering discipline to benefit from best practice in WBL from established training programmes in the life and physiological sciences
- build links with NHS employers and ensure graduates

are 'fit for purpose' and highly employable in the health service.

While this project relied heavily on close working with NHS hospital trusts, the process for developing a network of collaborating employers was not well thought-out in advance. A lack of financial support to implement MSC for hospitals, students or universities meant that we could not offer any monetary incentive for employers to get involved. In the life sciences there was already a culture of training undergraduates, but this was not the case for engineering. While we could argue the benefits of taking on trainees in terms of their unpaid contribution, training for existing staff and the opportunity to assess and shape potential new employees, we were largely reliant on the goodwill of employers.

The curriculum for the WBL was closely controlled by the MSC group at the Department of Health and adherence to this was a requirement for accreditation. Clinical engineering splits into four pathways, with students specialising in medical engineering, rehabilitation engineering, renal technology or radiation engineering, necessitating a programme curriculum with a mix of shared and specialist elements. In addition, the diverse stakeholder input into the curriculum, at a national level, has led to a dense and proscriptive set of knowledge, understanding and skills requirements. Due to the developmental nature of these courses, the details of this curriculum were not available until well into the project. This lack of guidance led us to follow an approach closer to problem-based learning than we would otherwise have taken. Rather than providing students with large amounts of structured study material, they were supported through their own searching of the literature.

Assessment for the WBL component of these courses comes in two parts: credit-bearing assignments and competency-based assessment. Phrasing of the assignments within the module descriptors allows scope for the tutor, mentor and student to tailor the submissions to the work conducted in placement. The emphasis on reflection on personal and professional practice intensifies with increasing academic level. This was seen as important, as reflective practice is not something that generally comes easily to engineering students. The competency-based assessment is managed through a national web-based system, developed with NHS West Midlands and recently put out to tender for full roll-out. Students can decide when they are ready to be assessed and submit an assessment request to an assessor of their choice. The assessment method can be direct observation of procedural skills (DOPS) or case-based discussion (CBD). The pass/fail status of the assessment and the feedback are then recorded on the system. This system has been adapted from one used in a formative context and we have worked with the providers to add functionality to allow tracking of summative assessment progress towards the



programme requirements. The engineering students have yet to experience DOPS and CBD and will need guidance in these new forms of assessment. The student-led assessment process was new to everyone. Once students became comfortable with this they made enthusiastic use of the system, collecting assessments on various aspects of their training as they went along.

The training of supervisors to perform a mentoring and assessment role was seen as a key part of developing these courses. Fortunately we were able to build on the existing training expertise in the School of Life Sciences (SoLS). However, the assessment processes for these courses were new to everyone and the whole process was new to the engineers. Supervisors were sent a number of training resources and invited to a two-day training session at the university. This session covered introductions to a number of general teaching issues, the degree courses, specific training issues and assessment. In addition, experienced mentors were invited to a half-day session on the assessment processes.

The briefing sessions for the students followed a similar format to those for the mentors. However, many of the students' concerns were of a more practical nature, such as transport and accommodation. The relatively short duration of placement, repeated placements throughout the course, potentially different placement locations and lack of financial support made these concerns rather different to those of traditional sandwich placement students. It will take time for us to develop the experience and administrative structure required to fully support students in this aspect of their training.

Students were visited by a university tutor twice during the initial ten-week training placement. In addition to this they were encouraged to make use of peer support, either through the university web-based systems or directly. Students also contacted university staff directly with specific queries but saw peer support as the most important way of sharing best practice.

Informal feedback was sought from supervisors and students throughout and this was used to help develop our processes. Formal feedback was also sought from both groups after their briefings and towards the end of the initial placements. By far the most productive route to establishing a group of collaborating employers was through existing networks such as professional and regional bodies

The main factors that employers reported for their involvement in placement training were:

- a need for employees with the knowledge and skills to be 'fit for purpose'
- the opportunity to assess the capabilities of potential employees and to shape their skill set
- the opportunity to shape the MSC implementation process.

Interestingly, while some employers did see the benefits of trainees as a 'free' extra pair of hands (the students are unpaid), this was a minority view. Trainees were generally seen as resulting in a net increase in workload for departmental teams. This will almost certainly be the case for the initial placement, where students are largely work-shadowing. However, as they progress through the course and develop their skills and understanding, they will arguably start to make a significant positive contribution in the workplace. It will be interesting to follow this up in future years to see how the perception of the value of taking on trainees changes as employers gain experience of the process.

Although only a small number of students have been on placement so far, the feedback from both students and supervisors has been very positive. Trainees rated all aspects of their placement experience as 'very good' or 'excellent', while supervisors rated the students as 'good' or better in all aspects of their training. The online assessment tool was also rated as 'good' or 'very good' across all factors.

We had considerable concerns about adopting a problem-based learning approach to WBL due to our expectation that students would have difficulty accessing library facilities at the university while on placement. In fact, this was not generally seen as a problem by students. Larger hospitals have their own libraries, but students made most use of online resources and their Athens accounts allowed them to access material as if they were based at the university.

Despite a number of setbacks, this project has been invaluable in the establishment of credit-bearing WBL in clinical engineering. The integration of placement learning at every stage in an undergraduate programme has proved to require a bigger cultural change than we had foreseen; however, the benefits to the student learning experience and the range of skills acquired are immense. Placement integration has posed practical challenges, such as timetabling and placement management, as well as more philosophical ones surrounding the purpose of higher education. The inclusion of competency-based assessment has been particularly challenging to notions of what engineering higher education should be. It will be interesting to see how the engineering professional bodies react to this programme format when we approach them to accredit the courses.

There have also been great benefits from working closely with employers which reach wider than this taught course. Employer-informed teaching and teaching contributions from employees has enriched our teaching across a range of subjects and has led to high levels of student engagement. The extensive employer network created for this project has also led to new research opportunities, collaborative partnerships and access to facilities. However, the administrative burden of developing and running this type of provision should not be underestimated.

This project has established the foundation for integrated WBL within these courses, but there is still considerable work to be done. As the students progress through their courses the number and variety of training placements that the university administers will increase until, once the first cohort graduates, we reach a steady state. We will also have new challenges to face, such as the implementation of work-based final year projects. The university is committed to sustaining these courses in the long-term, although the future of the MSC initiative is still less than certain.

For engineering in general, the integration of WBL into undergraduate programmes will be rolled out to other courses in a gradual way. This approach is already being used for part-time and foundation degree students within SoEDT.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/integrated_wbl.pdf**

Integrating industrial expertise into the delivery of an MEng aerospace engineering module

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A synopsis by the editorial team

Abstract

This project sought to develop an engineering module which would bring in experts from industry to educate future engineering specialists in aircraft product development in order to address the industry standards and codes of practice. The industry staff lectured on key aspects of aircraft design integration and collaborated with the academics involved in teaching this module. The proposed development was mapped against the current accredited MSc/MEng curriculum. The industry partners participated in the aircraft design project development and its technical quality assessment during the academic year.

The students' learning experience and employability was enhanced through the application of the theory in a practical module assessed according to industry requirements.

Keywords: **higher education, employability, assessment, aerospace engineering, aircraft design**

The practice of embedding employability into a curriculum has been a continuous concern for the higher education (HE) sector and the 2006 HEFCE report *Engaging Employers in Higher Education* stressed the need for the HE sector to improve collaboration with employers in order to enhance employability skills.

The rationale for this project was to close the gap between academia and industry in terms of hands-on experience and prepare students for the complex technical environment of industry. It sought to bring in experts from industry to provide the opportunity to educate future engineering specialists who can appropriately weigh technical, practical, business and management considerations in aircraft product development, whilst meeting the industry rigours and standards.

A core MSc/MEng module in which key aspects of fixed wing aircraft design are taught and the students are asked to work on a project on aircraft conceptual design, *Aerospace Vehicle Analysis and Design*, was used as a vehicle for collaboration with industry in terms of delivery and assessment, with the objective to encourage "deep" learning, making it relevant to industry and producing a strong and competent work force. The programme offers a working understanding of specialised information coming from industry expertise and this module leads to an enhanced design overview of technical decision-making and vehicle morphology analysis (taking stock of business case and risk), as well as systems integration, by presenting the industrial decision-making approach, integrated with business case and risk analysis, regulatory and operational considerations, marketing requirements and objectives. Highly complex cross-functional aerospace system architectures are governed by the edicts of technical, practical and business management. The specialised information is supported by advanced computational tools currently used in project delivery by academics (i.e. *Advanced Aircraft Analysis*, highly used in academia and industry), along with dedicated advanced CAD programs (i.e. *SHARX*, *AEROPack* and *Concepts Unlimited*).

In order to prepare students for the requirements of the industrial environment, the fixed wing aircraft design brief was prepared by the industry partners, the Future Projects Group of Airbus UK. Support from the industrial partners during the academic year was given through specialised lectures complementing the initial syllabus. The main phase of the project was achieved through a session of preliminary design review (PDR) by means of poster presentations carried out by the students a fortnight before final project submission.

At the PDR, each individual was given the opportunity, by means of joint staff panels, to present their preferred conceptual design option and the rationale for the choice to an invited audience of industrial and academic specialists. Each individual was expected to present details of a "Loop Zero" baseline design, which comes closest to meeting the specifications from the project issued by Airbus. At the presentation, the students were encouraged to convey an understanding of the nature of the specifications and the market (including competitor aircraft analysis). Finally, an account of the logic and rationale employed for down-selection from the pool of candidate aircraft morphologies was expected. The PDR presentation was a "walkabout review", where each student was visited by several panels of reviewers made up of industry representatives and academic staff (five or six per group). The students received feedback based on their technical acumen, critical review and understanding of their own research work, including critical steps in project management, communication and presentation skills. Based on this feedback, a *Final Engineering Definition Report* was compiled and submitted by each student, covering studies carried out in the initial phase and additional iterations in order to meet the full design specification.

After the PDR, a thorough discussion amongst industry members and academics took place in order to identify milestones achieved on the assessment day and throughout the project, student performance and what went well and wrong with the entire process. All panel members took part in the discussion and highlighted their own points on the status, including how to improve the process in the future. The meeting was minuted.

Two questionnaires were prepared for the industrial partners taking part in this project and for the students enrolled in this module respectively.

The industry panel was asked to answer the following questions:

1. What is (are) the value proposition(s) in such collaboration proposal (i.e. academia-industry) and what outcomes do you expect this (these) to have? What are your motivations for collaboration?
2. What difficulties do you envisage in developing collaboration with academia for the development of curriculum and student project assessment tailored to industry needs?
3. What skill set should students have developed during such collaboration? Would it suffice for employability?
4. Is this hybrid assessment formative and appropriate for students' development?
5. Realistically, what can be done to improve the links with the university for curriculum development and student project assessment tailored to industry needs?
6. To enhance student employability, what are the best ways of ensuring the student's profile (e.g., technical acumen, soft skills, numeracy, etc.) is tailored to industry needs?
7. What do you think are the main issues in the gap between industry and academia and how to address them?
8. What could be improved or changed to develop a sustainable collaboration with industry?
9. What haven't we asked in order to address and understand the main hurdles regarding student employability?

Below is a summary of responses:

- Industry considers that a link and a continuous dialogue with academia are essential for a shared vision and to shape the future. Recruitment of appropriately capable engineers is becoming increasingly difficult and any collaboration with universities should result in a better quality of graduates matching more readily the expectations of their potential employers
- Education should seek to find the compromise between academic need for breadth of understanding and industry need for specialised knowledge; academia should not seek to answer to a perceived industry demand but instead develop the ability to think and solve problems and avoid indoctrination with current methods and processes
- Industry could help to provide direction for the development and delivery of course material in order to enable students to be more exposed to its needs
- When recruiting, industry would like to see someone who has a general understanding of the design aspects, can learn quickly, has good problem-solving skills in a complex environment, can think critically and laterally and articulate results. The ability to listen and communicate thoughts and ideas to others and to make and defend technical decisions can only help their chances of employment. Internships, one-year or summer industrial placements, group design projects or final year projects based on industry input, can enhance the chances of future employment by developing the skills needed by industry
- It is difficult to establish a constant stream of

information and communication between industry and university, and a tailored project such as this one seems to be an excellent endeavour

- The assessment carried out together with industry is highly valuable, as it gives the students a taste of the real world, challenges their thought processes and gives them extra motivation, helping them to question their own work and provide a context for it. It improves the level of soft skills, making students better technically equipped for interviews
- Industry wants to see a return on its investment, with the need for a business case for continued investment and growth, and this kind of exercise proves to be equally useful for students and industry, giving the students a better understanding of what is expected from them in similar situations and helping them after they finish their studies.

Students were asked to complete an evaluation survey which was used for analysis of the learning process and the impact on the student learning experience. This approach captured any "lessons learned", both from technical and project coordination perspectives, along with skills attained. The survey was also used as a sounding board for any strong objections to the critical assumptions adopted during the course of the project.

A questionnaire was developed, based on previously published research, analysing the problem-based learning efficiency. The questions highlighted good teaching practices, clarity of teaching objectives and engagement, as well as assessment and workloads in relation to the development of the proposed skills for an engineering module. The questionnaire was organised into six sections: good teaching practice, clear goals formulated during the project, the assessment difficulty, workload perception, skills enhanced during the project and the efficiency of student engagement.

To assess the quality of the teaching process in a metric format based on the students' perceptions and needs, the approach developed by Mousavi for analysis of quality in product design was used. In this approach, quality can be interpreted as the degree of user satisfaction with product attributes. The approach, linked with the Prospect Theory developed by Mowen, uses a quality measurement to reflect the relationship between the user's requirements and the adopted design. This can determine a scale and become an aid for decision-making in evaluation of the customer's preferences and product improvement.

The analysis of the questionnaire responses about teaching practice revealed that the activity was perceived as challenging and required effort to understand and integrate the knowledge for the design process. The academic and industrial partners were working hard to motivate the students, make the subject interesting and comment on their work, encouraging them to take ownership of the project. The aircraft design project

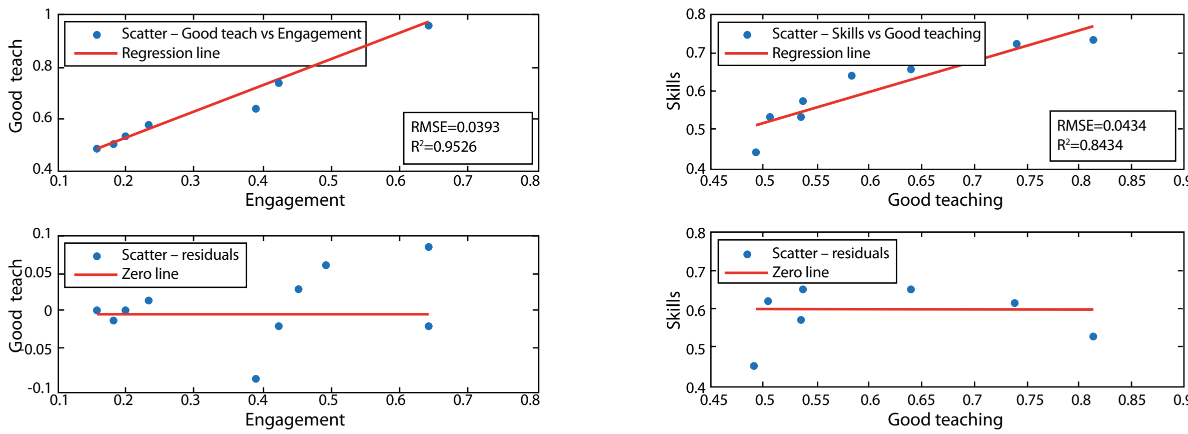

Figure 1. Relationship between good teaching practice and student engagement and skills development respectively

required the application of knowledge from aerodynamics, flight mechanics, aircraft performance, etc., and filtering all of this knowledge in a creative manner at the industry level of requirement was not an easy task for students or for the academic delivering the teaching.

The fact that the design exercise was an individual task is reflected in lower scores for the questions specific to group work, although discussion with peers during the project was helpful. The project complexity, which in its progression represents a non-linear process, is acknowledged, with final goals seeming distant in different phases for the students. But these difficulties led to something special: the students learned how to plan their work better in the context of very clear requirements in terms of results and work standard.

The evaluation reveals that the design exercise required an in-depth knowledge (i.e. not just memorising things) and during the design exercise the students had the opportunity to develop their own ideas and redirect the project requirements towards their own solution.

It was recognised that the workload was high, with the students having a lot to learn and feeling the pressure to finalise the project at a high standard. But the reward was obtained through the skills developed during the project. At the end, the students felt confident that they could prepare a complex technical report, present their ideas in front of an audience and defend their work, find and analyse complex information and demonstrate an improved ability to solve difficult problems. Finally, the students enjoyed working in this way, as evidenced in the engagement section of the questionnaire.

These results are confirmed by the trends presented in Figure 1, showing the correlation between good teaching practices and student engagement and skills development respectively.

In summary, the aircraft design project given by the industrial partners required the students to engage with a complex situation, be active in their learning and structure their knowledge and learning processes, enhancing the student experience and promoting quality learning. The interaction between industry specialists and academics provided an opportunity to introduce experience–led teaching into the aerospace engineering programme and prepare this degree to be fit for the future.

This project sets a new strand in teaching innovation and is a model for bridging the skills gap between academia and industry. By developing similar teaching innovation projects, a stronger partnership can be achieved with key industry players so that companies' standards can be implemented into the curriculum to develop students who are suitable for current market industry needs.

The increase in student employability represents a strategic programme for the School of Engineering and the success of this project means that this will continue as an exercise to enhance the student experience, learning from its triumphs and challenges alongside our industrial partners. The employers' evaluations and suggestions will be taken into account for further continuation and development of good practice and future active involvement of the aerospace industry. The relevant recommendations and conclusions will be used for all of the courses and the development of new initiatives for further curriculum innovation within the School of Engineering and Design.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/meng_aerospace_module.pdf**

Industrially-owned modules for HE

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A synopsis by the editorial team

Abstract

This project allowed industrial partners to work in collaboration with academics in the design and delivery of specific modules. The project successfully developed three 'company-sponsored' modules with representatives from civil engineering (BAM Nuttall), chemical engineering (SABIC) and project management (Jacobs Engineering) companies who were able to draw upon their experiences of the strengths and shortcomings of recently appointed graduates in order to enhance the employability focus of the modules. The evaluation provided evidence that students benefited from the explicit involvement of industrial partners and supported the assertion that 'relevance motivates'[1]. The principles and approaches adopted in this project should be transferable across the wider HE STEM sector.

Keywords: **industrially-owned modules, relevance motivates**

1 Lamb, F., Arlett, C., Dales, R., Ditchfield, B., Parkin, B. and Wakeham, W. (2010) *Engineering Graduates for Industry*, London, The Royal Academy of Engineering.

The School of Science and Engineering at Teesside University operates an external advisory board consisting of scientists and engineering company managers, employers and representatives of professional organisations. The board meets regularly with the school's senior management team, which includes the Dean and Assistant Deans, to review courses, training and employment opportunities for our students and to advise on curriculum and new course development. The school has been implementing a number of ambitious plans to achieve this, including the redesign of all 25 of its undergraduate courses around an innovative structure based on a core of sequential integrating problem-solving modules which require students to demonstrate their ability to apply their learning in context before progressing to the next academic stage. The industrially-owned modules are one further element which we hope will provide further relevance and contextualisation of the learning and are consistent with this approach.

Involving the industrial partners who agreed to work with us in the development and delivery of modules around their business needs within the curriculum is consistent with the strategy set out by the Department for Business, Innovation and Skills (BIS) for universities to provide the high level skills needed to remain competitive. This specifically identifies the need for business to be more engaged in the design of programmes. Furthermore, there is considerable evidence to suggest that, where the curriculum has been enriched by industry-relevant modules, student engagement and increasingly important metrics (such as retention, NSS scores and employment in graduate careers) improve.

The project's aim was to increase student interest and motivation and better equip students to understand the context and application of their learning. It was considered to be an extension of the employability-led agenda within the school which permits the link between theory and practice to be further reinforced within the curriculum and to permeate across all programmes. It was intended as a pilot which could eventually roll out to every course in our engineering portfolio and a number of science courses as well.

The key objectives were to:

- Ensure the link between theory and practice is further reinforced across our programmes
- Achieve explicit industry-led input into the design of the curriculum
- Improve student engagement
- Provide a flexible model for the creation of industry-owned modules in partnership with academics.

The anticipated outcomes of industrial involvement in the design and delivery of modules associated with undergraduate engineering programmes were as follows:

- Improved motivation of students premised on the clear relevance of the taught curriculum
- Improved retention, NSS and employment outcomes
- Development of a series of industry-owned and badged modules
- Dispersal of this approach across all of the school's science and engineering undergraduate awards
- Adoption of this type of model by the wider HEI sector.

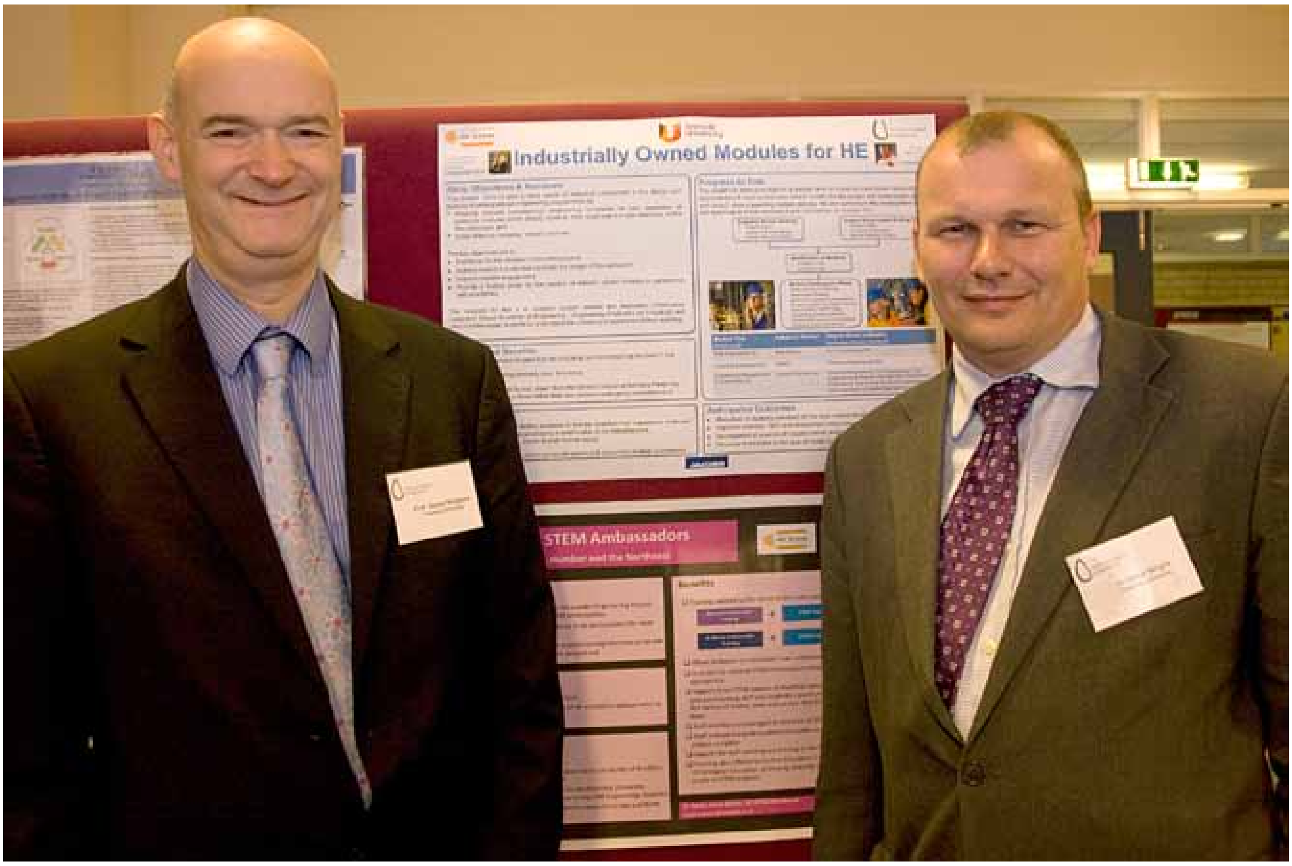
The project piloted a novel model of industrial involvement in the design and delivery of undergraduate engineering programmes by allowing relevant (volunteering) engineering companies to take ownership of particular modules within the curriculum which relate directly to their organisation's core business and badge them as 'company-sponsored' modules. The three industrial partners were large multinational organisations that had a wide range of material on which to draw for their activities. In addition, they were significant UK graduate recruiters able to draw upon their experiences of the strengths and shortcomings of recently appointed graduates to help in the design of the modules. All of the company representatives were drawn from the School of Science and Engineering's external advisory board.

Initial meetings with the industrial representatives were used to introduce them to the structure and organisation of the School of Science and Engineering's undergraduate engineering portfolio. An outcome of these meetings was the identification of a set of criteria that would be used to select the three pilot modules. The criteria were as follows:

- Must align with the area of industrial expertise of the partner
- Must be either a first or second year module (level 4 or 5)
- Ideally, should be a module that covers content that students struggle to grasp the relevance of or struggle with academically
- Ideally, the module will *not* be a group project module.

The industrial representatives were provided with specifications of the six disciplines offered at undergraduate level and a comprehensive module catalogue from which to identify modules to which they would be interested in contributing.

In the second round of meetings, representatives from the industrial partners met with subject group representatives of each engineering discipline to identify the specific modules to be developed. The three pilot modules identified were *Risk Assessment, Control and Simulation* (both degree-specific) and *Engineering Management and Leadership* (cross-disciplinary). All three modules were associated with the second year of study of full-time students (FHEQ level 5) and are compulsory. The three industrial partners felt that the modules selected for the pilot clearly reflected their expertise and covered content that students struggle to grasp the relevance of or struggle with academically. In the case of the *Risk Assessment* module, the industrial partner, BAM Nuttall, felt that students frequently underestimated how the application of this discipline underpinned the commercial activity and reputation of the whole sector. SABIC wanted to be involved in the development of the *Control and Simulation* module primarily because they recognised lack of experience in this area as a shortcoming of recently appointed graduates. The selection of these two modules, which are delivered to two separate engineering disciplines, conforms to the original proposal. It was initially



planned that the project would focus on developing two modules which would be delivered to differing degree cohorts; however, the addition of a third partner allowed the inclusion of *Engineering Management and Leadership*, a module which cuts across all of the engineering disciplines. The expertise of Jacobs Engineering (Aker Solutions) made their involvement in this module appropriate as they were able to draw on a wealth of business experience in multidisciplinary projects relevant to students from all of the different disciplines.

Identification of specific modules permitted the individual module leaders to liaise with their corresponding industrial partner to review the content, assessment strategy and learning outcomes associated with the module specifications, whilst simultaneously considering professional body requirements/expectations. Only minor modifications were required to the module specifications and, where necessary, these were dealt with by the school's Academic Standards Committee. The detailed module development, particularly in relation to defining the nature of the industrial partner's contribution, occurred during the summer prior to the delivery of the modules. These agreed contributions currently include activities such as guest lectures and provision of case studies and pilot plant data to support the taught provision and assessment strategy (SABIC). BAM Nuttall suggested that greater emphasis be placed on some of the existing indicative content, for example, environmental and commercial risks being covered by guests from industry. Jacobs were instrumental in the redesign and development of the learning strategy for the management module and then endorsed the assessments to the students. The students were informed of the involvement of the industrial partner in the development and delivery of the module, and the rationale for this involvement, in the first taught session. This typically included an introduction to the module delivered by the industrial representative.

Student feedback for these new modules was elicited in late December 2011 (as we approached the end of the first term). It should be noted, however, that it was not possible to complete these modules within the timescales of this project and therefore evaluation is based on an interim assessment of the students' perceptions of the modules, principally carried out using a short questionnaire which was the same for each module and consisted of three sections:

1. Background information (e.g. home or international students)
2. Ten goal-oriented statements relating to the project objectives. Students were asked to indicate their degree of agreement using a Likert scale ('strongly agree' to 'strongly disagree'). Questions 1 and 2 focused on how students perceived the principal of industrial involvement in the development and delivery of the module. Questions 3, 4 and 5 focused on whether industrial involvement in the development and delivery of the module content and assessment had contextualised the material and increased student interest, motivated engagement and enhanced the relevance of the topics covered. Questions 6, 7 and 8 queried whether the involvement of the industrial partner had improved the relevance of the material covered in relation to their degree, professional expectations and personal development. Questions 9 and 10 were used to assess overall satisfaction with the module and inclination to recommend it to another student
3. Free-text, inviting brief suggestions about any particular contribution that students would like industrial partners to make and any factors, other than the involvement of an industrial partner in the development and delivery of the module, which positively or negatively influenced their experience.

The student perception of the principal of involving industrial partners was very positive. Furthermore, contextualisation of the learning, by involving the industrial partners in the design and delivery of the modules, appears to have had a positive impact on student engagement with them. The majority perceived the involvement of industrial partners as a positive influence in their assessment of the modules' relevance to their studies and future careers. Despite the positive perception of industrial involvement in the development and delivery of the modules, a small minority of students appeared to be dissatisfied with or felt unable to recommend these modules to other students. The highest levels of dissatisfaction were associated with the cross-disciplinary *Engineering Management and Leadership* module and mostly criticise its timetabling, which was governed by the availability of the external lecturer and does expose a potential shortcoming of the more widespread involvement of industrial lecturers in programme delivery as they have to work around their other commitments. In terms of suggestions about any particular contribution students would like industrial partners to make, the majority requested either an increase in the number of guest lecturers or the opportunity to undertake site visits.

It appears, at least from the perspective of the interim evaluation, that engineering students are in favour of the explicit involvement of commercial companies in the development and delivery of modules on their degree programmes. In engineering disciplines, typically associated with high levels of graduate employment, the acceptance of the explicit involvement of industry is not surprising. However (although not an issue in our pilot), it was observed that students from certain other related disciplines (for example, environmental science) may oppose this type of explicit involvement by commercial companies as an adverse influence on the balance and objectivity of their course. Comments derived from the questionnaire suggest that students would like the involvement of the industrial partner to be extended (e.g. guest lecturers and opportunities for site visits).

Overall, it is clear that failure to engage with effective mechanisms of delivering employability skills as part of an award is likely to adversely affect the currency of a UK-based engineering degree. Universities will require a variety of delivery models which encompass varying degrees of commitment on the part of the industrial partner in terms of time and money. This project has successfully developed three industrially-badged modules. This model allows industry to make an upfront investment to tailor the design and delivery of a specific module to meet their needs. The extent to which they wish to participate in the delivery is then determined in partnership with the academic lead, although this does not preclude other parts of the curriculum engaging in more intensive interaction with industry, up to and including course sponsorship. The pilot also provided further evidence supporting the assertion that 'relevance motivates', expressed in the recent Royal Academy of Engineering report *Engineering Graduates for Industry* (**http://www.raeng.org.uk/news/publications/list/reports/Engineering_graduates_for_industry_report.pdf**).

A full evaluation of these modules will be subsequently conducted and used as part of ongoing evaluation of the success of the project. We will attempt to measure the difference between student performance on this module against average performance for the respective cohorts on other modules and compare this data against trends in previous years on the modules which these new developments will have replaced.

The approach to engaging industry/employers in the design and delivery of our curriculum will be embedded in future occurrences of these modules and extended to include other modules and disciplines. Although this pilot study was specific to the particular modules and courses within our own university curriculum, the principles and approaches should be transferable across the wider HE STEM sector. The school's operation of an external advisory board, which meets regularly with the school's senior management team, has been critical to this development as it permitted a route via which industrial partners could be recruited. It is envisaged that the continued operation of the advisory board will be critical to sustaining and extending the project across new modules. Similarly, the participation and support of the senior management team meant this development could strategically select modules, in line with the HEA's recommendations in *Embedding Employability into the Curriculum* (**http://www.heacademy.ac.uk/assets/documents/employability/id460_embedding_employability_into_the_curriculum_338.pdf**), rather than permitting them to occur at potentially variable levels across awards.

The full case study and literature references can be found at:
www.hestem.ac.uk/sites/default/files/industrially-owned_modules.pdf

Re-engineering assessment for engineering education

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A synopsis by the editorial team

Abstract

This project sought to enhance the student learning experience and engagement by re-engineering assessment. It started with identification of specific assessment issues in engineering disciplines and then explored possible solutions by building fit-for-purpose assessments to engage students with their learning, particularly in terms of supporting level 4 students' transition onto their degree courses. Timely and effective feedback mechanisms were also developed to enhance the student learning experience.

The project team has successfully achieved the following outputs and outcomes:

- Development of more learning-oriented methods of assessment
- Enhancement of the student learning experience through re-engineered assessment activities
- Design of assessment that supports the transition into higher education.

Keywords: assessment, learning-oriented assessments, learning experience

As part of a year-long, university-wide assessment project, the School of Engineering and Technology at the University of Hertfordshire had started to review its assessment strategy and explore how well it was meeting the need for a student-centred and learning-oriented experience. The school found some excellent examples of learning-oriented assessment and wanted this to be the experience of all of its students by:

- embedding assessed tutorials to encourage students to keep on top of their learning
- using peer assessment to help students understand what is being assessed
- using phased assignments to encourage students to take notice of feedback
- designing regular small assessments to encourage students to distribute their efforts more evenly across their studies.

In this project, the team aimed to extend these activities by identifying issues of assessment that are specific to engineering disciplines, for example assessing practical and analytical work and exploring solutions for issues/problems identified. The project also looked at how these solutions could support level 4 students' transition onto their degree courses.

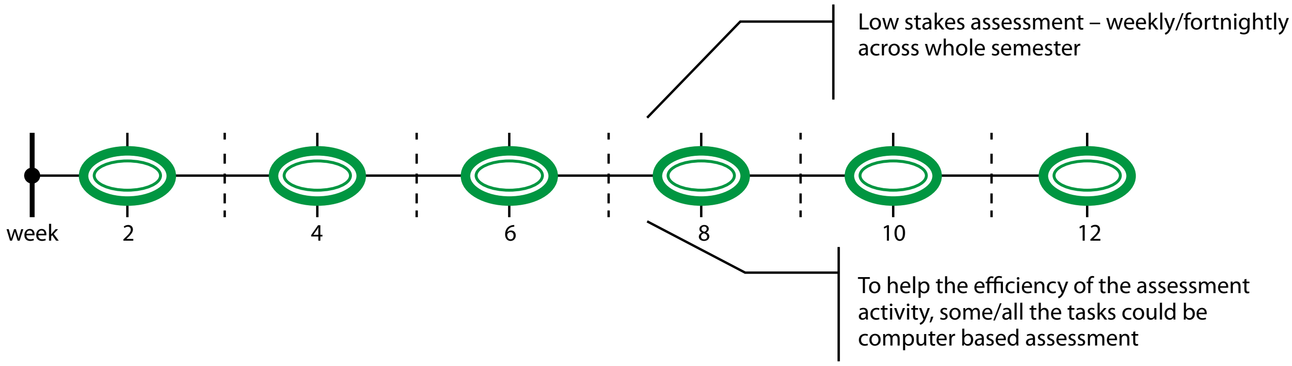
The project started with the process of evaluating current assessment methods, with a particular focus on identifying specific assessment issues in engineering disciplines. Particular attention was given to assessment of the outcomes/competences identified in UK-SPEC. The advice of sector employers and professional bodies was obtained to support this process. Based on the issues identified, the project explored possible solutions by building fit-for-purpose assessments to engage students with their learning, particularly in terms of supporting level 4 students' transition onto their degree courses. The project team inducted staff during school staff meetings. Leaders of 26 modules across the target programmes volunteered to take part in the project and review assessment strategies for their modules.

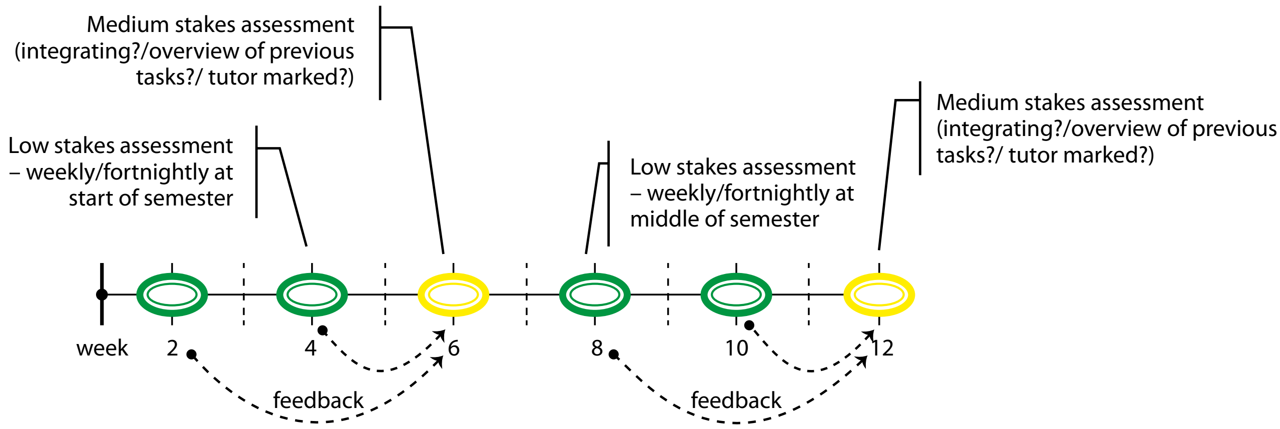
An Assessment Workshop was organised within the school at which assessment strategies for the target modules were discussed and designed. The following good practice/strategies were derived as the outcomes of the workshop:

- Adoption of In-Course Assessment (ICA) methods that would not increase the time burden on students
- Development of timely and effective feedback mechanisms to enhance the student learning experience
- Targeting modules in early years and only using 100% ICA in the final year when an exam would be inappropriate
- Regular consultations with professional bodies
- Employment of postgraduate students to process computer-aided marking methods.

The assessment strategies were designed to:

- encourage consistent student engagement
- spread the assessment load for both staff and students
- give ample opportunities for feedback to help students
- allow student performance to inform teaching materials.





With these developments, the next step was to explore responses to the sector-wide potential challenges related to assessment:

- Timing and bunching of assessments
- Plagiarism and collusion prevention
- Problems with large cohorts
- Staff loading
- Staff IT skills.

Based on the strategies developed, a school Learning and Teaching Away-day was held to enable staff to share good practice in assessment methods and prepare them for the design of new assessment tasks in the coming academic year.

Table 1. Typical module

Lab exercises 1–5	Practical work	40%
Formal lab reports/ phased assignments	Written report/ assignments	40%
Phase test	Class test (multiple choice questions)	20%

The new assessment tasks were designed and implemented by the module teaching teams during Semester A in the academic year 2011/12.

The generic redesigned assessment strategies consisted of several common elements: a series of laboratory exercises, laboratory report and phase tests, etc. Module leaders planned their module assessments according to the module content and student learning experience. A typical module is shown in Table 1.

Evaluation was approached from three directions: the target students, module leaders and student performance data. Student feedback was obtained via Student View Point, the university's student feedback portal for modules. Feedback from staff was collected via email and face-to-face discussions. Student performance data was obtained following the Semester A Module Boards. Overall, feedback was very positive and the new assessment strategies and tasks were welcomed by all stakeholders. With the redesigned assessment strategies and tasks implemented in Semester A of the academic year 2011/12, the pass rate of all of the targeted modules increased by an average of 21% as a result of better student engagement and an enhanced learning experience.

Staff were of the opinion that redesigning the assessment strategies had led to fairer assessment (student performance no longer depended on a single exam mark) and a more evenly spread assessment load for both staff and students, that the Assessment Workshop and school Away-day were useful, that low stakes regular assessments enhanced student engagement throughout the module and that student motivation had increased as a result of more and earlier feedback from tutors.

Students were of the opinion that the regular and phased assessment elements helped to break difficult topics into manageable small parts and reassure them that they were on the right track, that the new approach had sustained their interested and engagement throughout the module and that the regular tutor feedback helped them to understand where they had gone wrong and what to do about it. One of the targeted Semester A modules, *Material and Electrical Technology*, is a level 4 module with a cohort size of 116. Five phase tests were built, one after another, and were supported by laboratory practical experience. Calculation of the final marks was based on the best four out of the five tests. Students appreciated the calculation method, as they felt they had no need to panic if, due to extenuating circumstances, they didn't perform as well as they should have in one of the tests. In fact, all of the students attended all five of the tests in order to achieve the best performance possible. Furthermore, this assessment strategy made them feel rewarded and motivated, as they could use the tutor's feedback to improve their performance in the next test.

The redesigned assessment strategies and tasks were also highly commended by the external examiners in the Semester A module exam boards:

- A variety of assessment tasks was designed and implemented, with particular focus on hands-on practices
- Assessment tasks were deemed suitable for module learning outcomes, with appropriate difficulty levels and feedback mechanisms
- Assessments were embedded with professional skills development to enhance student employability.

The project has successfully achieved the following outcomes:

- Development of more learning-oriented methods of assessment
- Enhancement of the student learning experience through the re-engineered assessment activities
- Design of assessments that support the transition into higher education.

The project outcomes have directly benefited students by providing them with better and more continuous feedback; better engaging them throughout their studies to improve retention. Staff were supported to work through curriculum and assessment designs in order to ensure appropriate outcomes.

Whilst at school/college, students are given repeat attempts at assessments in order to gain better results, but this is not the case at university. It is very important for a degree programme to manage level 4 students' expectations of assessment and help them to adapt to the higher education environment more smoothly. The redesigned assessment strategies have narrowed the gap between these two systems by giving students regular low stakes assessment opportunities. As well as giving them a sense of security by spreading assessments across the whole module, the approach helped students to understand the boundaries of the higher education assessment system.

The project team sought numerous opportunities to both learn from and disseminate the project experiences and examples of good assessment. The project findings have improved the sector's understanding of and practice in the use of assessment to enhance and engage students with their learning. The redesigned assessment models/strategies have been made available to other institutions wishing to introduce them into their engineering curriculum.

In terms of further development, the redesigned assessments will be reviewed regularly by the programme teams, together with advice from employers and professional bodies, so that the sector's development trends can be embedded into the continuous development of the programmes to ensure that the latter meet the changes and dynamics of both employer and student expectations.

The project team has been working with staff on their values and beliefs about good education and, in turn, good assessment, and it is important to ensure that this project is sustainable.

The full case study and literature references can be found at:
www.hestem.ac.uk/sites/default/files/re-engineering_assessment.pdf

Development of the online interactive software "Push Me-Pull Me"

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A synopsis by the editorial team

Abstract

The project aim was to develop the online interactive software for qualitative structural analysis "Push me-Pull me" (PmPm) in **www.expeditionworkshed.org**, a website dedicated to civil and structural engineering students that is created and maintained by Expedition Engineering's educational arm ThinkUp. Specifically, guidelines for the use of PmPm within the Workshed were developed to enable its use as a free tool in higher education institution virtual learning environments, including tutorial exercises in worksheets purposely created to engage students and enhance their intuitive understanding of structural behaviour. Finally, the use of PmPm in parallel with formal lectures was promoted through visits and workshops.

Keywords: qualitative structural analysis, online educational tools, engineering education

The use of virtual learning environments (VLEs) in higher education is becoming more widespread, with the increasing availability of fast internet service greatly improving the accessibility of learning material. The use of multimedia in problem-based learning can create a richer learning experience, individualising practice, feedback and reflection and these systems can host computer-generated models which perform the function of a "laboratory at home". Especially in fields such as science and engineering, enquiry-based learning through computer-generated models can improve understanding of scientific/engineering concepts by providing students with an easily accessible and tangible experience. In this context, "Push Me Pull Me" was developed by Expedition Engineering (EE) as a response to the growing number of engineering students lacking an intuitive understanding of structural behaviour. The online tool "Push me-Pull me" (PmPm) (**www.expeditionworkshed.org**) was developed further, with guidelines for its use and worksheets to be used as a "bolt-on" in structural analysis modules mainly for the benefit of civil and structural engineering students.

Traditionally, structural analysis modules are mostly quantitative and very little time is spent on the important concepts of line modelling and the relationship between kinematics and statics. Students see structural analysis as a mathematical subject and this often gets in the way of their development of an understanding of structural behaviour. PmPm has filled a void by relying on conceptual interactive diagrams which appeal to modern students and introduce fun to the learning process.

The PmPm project had two target audiences: primarily academics, who upon introduction would opt to use it in class, and secondly students. During the development of the online tool, the authors introduced PmPm models in class, whereupon students verbally fed back that they thought of it as a fascinating alternative to traditional tutorial time and even simple finite element packages (which require a quantitative procedure before the analysis result can be seen). Between Brunel University, the University of Birmingham and Strathclyde University, approximately 150 students used it during its development. The tool was also presented to structural analysis academics from across the UK on two occasions during a series of workshops on the future of the teaching of structures organised by the Institution of Structural Engineers (IStructE). During these presentations, around 30 academics were introduced to the tool, the supporting worksheets and the potential benefits to their teaching.

The tool consists of a number of 2D structural models (beams and frames) which are first shown as renders (i.e. as if they are real steel structures). Then, by switching on the "model" button, the line (weightless) model of the structure is revealed, as well as several buttons denoting deflection and stress resultant distributions (bending moment, shear and axial force) in different colours. By moving the cursor and pressing the left mouse button, the user can push and pull the models, watching the deflection and stress resultant distributions change as they move the load along the structure. The stress resultants can be switched on

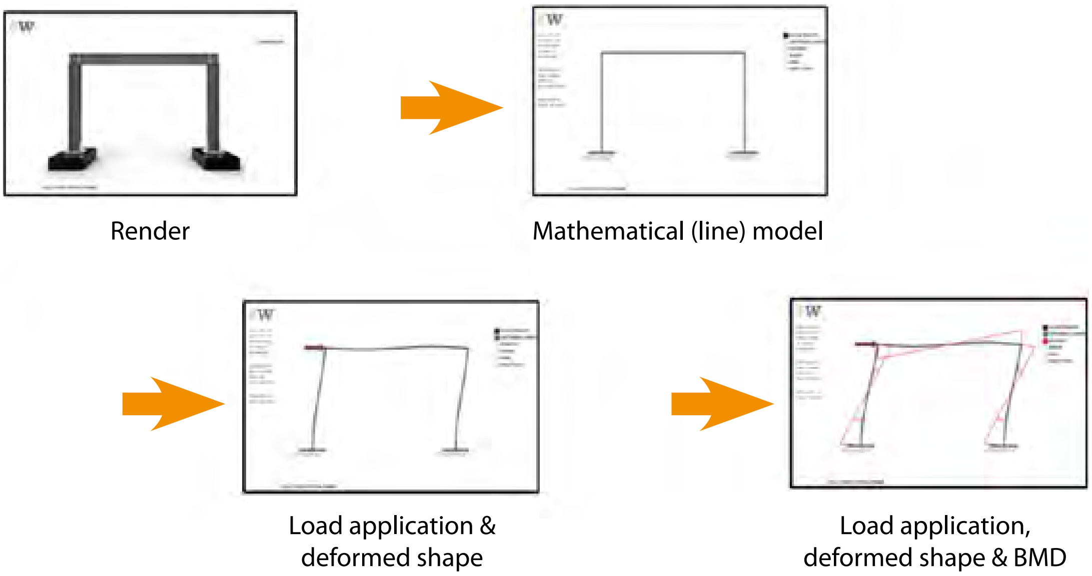


Figure 1. One of the various PmPm models, firstly as a render, then as a mathematical model, applying a load, observing the deflected shape and then superimposing the bending moment distribution

simultaneously in any combination, while pressing <Enter> will freeze the loaded configuration (see Figure 1).

More than 20 models exist on the Expedition Workshed website and, to help both students and lecturers, the group decided to create guidelines and worksheets for their use, focusing on some of the key areas of qualitative structural analysis that would enhance the students' intuitive understanding of structural behaviour. These areas include stress resultant sign convention, line modelling of real (steel) structures, deflections of 2D beams and frames, loads and reactions, reactions and shear force diagrams, bending moment and shear force and finally bending moment and deflected shape. These worksheets are easily viewed online or can be downloaded at no cost under a creative commons licence. They are brief and simple so that they can easily act as a "bolt-on" in any structural analysis module in any country or can be used by individuals (either students or recent graduates) for practice at home. The worksheets were purposely created to fit easily within taught structural analysis modules, either to be used in class or as homework for improvement. They are designed to be straightforward, with brief, simple sentences that guide students through a prediction-validation routine where they are first asked to predict structural behaviour qualitatively by sketching deflections, assigning reactions and drawing approximate stress resultant distributions. They then have to validate their predictions using PmPm.

The worksheets can be accessed online at **www.expeditionworkshed.org** by following Staffroom and Push Me Pull Me Worksheets, while the PmPm models can be found by following Workshed, Models, Push Me Pull Me.

PmPm worksheets were used in class with level 4* students at Brunel (*Fundamentals of Structures* module) and also level 4 and 5 students at the Cyprus University of Technology (CUT) (*Integrated Design for Civil Engineers* module). The format in all occasions was quite similar, since each worksheet included a short introduction to each topic, which was well suited to even Level 4 students who had not yet been exposed to stress resultant distributions. In fact, introducing concepts such as bending moment and shear force diagrams through the qualitative and dynamic environment of PmPm (and before formal teaching of the mathematical quantitative derivation) helped students to better understand the concept of these distributions before they started worrying about getting the mathematical analysis right. This was evident by the quality of Level 4 "Design and Build" project work and supported by student comments in the questionnaire that followed.

Giving students the chance to predict possible deflected shapes due to a point load or the approximate shape of a bending moment diagram is quite empowering. Furthermore, the fact that afterwards they were given one of their peer's work to review using PmPm and would be mostly marked on the quality of the review and the feedback they would give to their peers provided them with the opportunity to experiment further with the tool and think about how to explain the behaviour, rather than

* Brunel University refers to year groups as levels, such that year 1 is level 1. The references to levels here are based on the UK-wide system for consistency with other case studies funded within the programme; therefore a level 4 student in this context would be an undergraduate year 1 student or a level 1 undergraduate at Brunel University.

just marking something as right or wrong. In each of the three sessions there were more than 40 students.

At Birmingham, Level 6 MEng students, as part of their course, are used as mentors for level 4 students in different activities. One of these activities is a design, build and test competition that involves a significant amount of design and report work and culminates in the construction of a trussed bridge structure. This is part of the level 4 module *Statics and Mechanics* and is an excellent vehicle for Workshed. In the briefing document produced by level 6 MEng students, level 4 students were specifically encouraged to use and evaluate their use of Workshed in support of the design of their structures. Positive feedback was received from both level groups. Similar student responses were also seen at the University of Brighton, a workshop was run for 30 level 4 students on the deflected shape of framed structures.

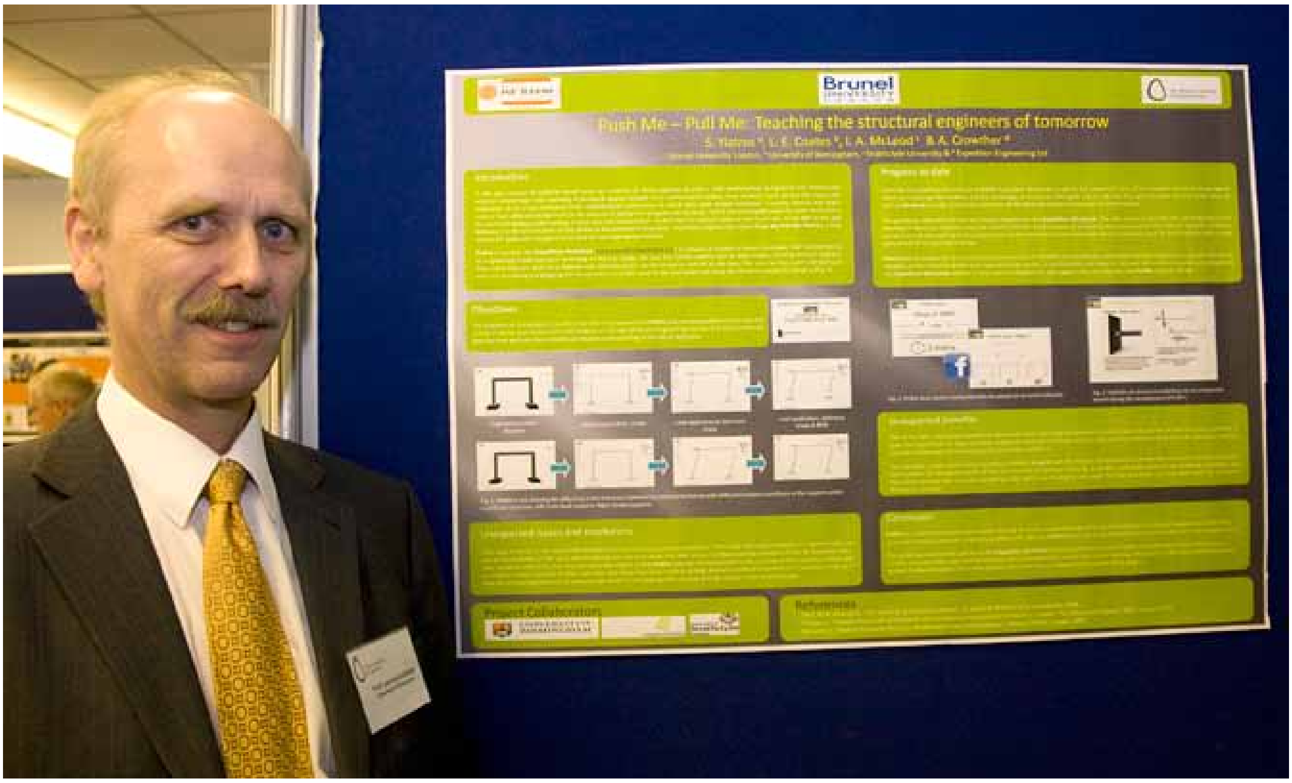
At CUT, the first three worksheets were used for assessment. 30% of the grade was given for correct predictions and 70% on the review, which included provision for feedback and constructive comments. The quality of the review work was very good, something that was not only highlighted by the high marks for both level groups, but also reflected in student engagement with the subject. Having seen the impact it had on CUT level 4 students, it was decided to use it for the *Bridge Design and Build* project, which required students to perform qualitative structural analysis using PmPm models, and "Catastrophe", a sister game/tool on the Expedition Workshed website. In Catastrophe, students could make their own structure using nodes and line elements and then push it and pull it to examine resulting deflections and stresses. Using a combination of these two tools, students had the opportunity to model, analyse, build and test structures by making rational observations without the need for training in structural analysis software.

Evaluation of the impact of the project was based on the following:

- The response of the students who used it as part of their taught modules, through verbal feedback and through a bespoke questionnaire
- The number of lecturers agreeing to incorporate it in their teaching.

At Brunel, where the first student workshop took place, students were in general quite excited about PmPm and some even volunteered to contribute by trying out new models. In fact, through student feedback, it was possible to fix small bugs in the applets as well as some minor problems with sign convention. The tool was introduced at CUT after these amendments and website refurbishment had taken place which greatly improved accessibility to the models and worksheets. Despite the fact that the presentation was made in Greek (the taught language at CUT), students had no problem using the tool and the worksheets, demonstrating a truly global perspective and potential impact.

Testing true impact on the teaching of structural analysis and the development of students' intuitive understanding



of structural behaviour is quite difficult within the lifespan of this project. As an initial measure, verbal feedback in class, a student questionnaire, verbal feedback from the academic workshops and website statistics which show the traffic on the website were used. The initial results from the questionnaire (41 responses to date) rate several aspects of the tool (accessibility, quality of explanations, sign conventions, etc.) very favourably, with about 90% of the respondents selecting "very good" or "good". Similar positive results were observed in the question about the improvement of understanding of different aspects of structural behaviour where the response was overwhelmingly favourable. In the question regarding how PmPm is most commonly used, the majority answered "for private study" as opposed to "in class", indicating that students had begun using it frequently. Indeed, results from web statistics show that in the first two months since its re-launch the Workshed had almost 5000 users, of whom approximately 42% were recurring visitors. The statistics indicate activity not only from England, but also Europe, North America and Australia. Despite the fact that these statistics refer to the Workshed website traffic and not PmPm itself, the increased level of activity in the areas that PmPm was introduced indicates a positive outlook for the tool.

On the academics' side, Professor Coates represented the group at a dissemination event at Coventry in September 2011, where a number of academics expressed interest in the project. The participants in the IStructE workshops have recently been notified of the latest developments of the project and the uses in class. To date there have been five responses indicating that it is an interesting prospect and is being considered for integration in courses. Unfortunately, the timing of the communication (being towards the end of the second term) does not allow for its immediate use, but at the time of writing the group has been using personal contacts, social network websites (e.g. Facebook, Linkedin) and the Expedition Workshed blog to inform the academic community about PmPm and widen its use.

The completion of the project exhibited minor differences in the dissemination from what was envisaged in the beginning, as it was decided (for environmental reasons) not to print paper booklets for academics. This decision was taken without compromising accessibility of the material, since it would all be available without cost and online. Instead, resources were focused on communicating the work at academic workshops such as the IStructE workshops and the IABSE conference in London. Furthermore, the verbal feedback from the PmPm class activities at both Brunel and CUT demonstrates a positive outcome of the project which is backed by the questionnaire results and increased activity on the website.

In summary, this was an ambitious project to create an interactive tool to assist students' learning of structural behaviour in a qualitative way. PmPm, a great idea by EE, is now complete, with a set of worksheets and guidelines for its use in class. Without the worksheets the tool has limited capabilities as a teaching (visualisation) tool, as only the keenest students will experiment with it and then, in all likelihood, forget about it. The absence of a structured learning pattern would probably lead to a deceptive clarity of structural behaviour, as shown by studies in the use of interactive visualisation tools in science subjects. Quoting a student response to the question *Which worksheet was most useful and why?*: 'Push Me Pull Me helped me understand the direct relation between SF and BM using a simple exercise without any calculation', while another went further by comparing the potential learning of PmPm to the work that can be done in a statics laboratory exercise. The aim of these worksheets is to overcome this deceptive clarity and create knowledge integration patterns as the intuitive understanding of structural behaviour develops.

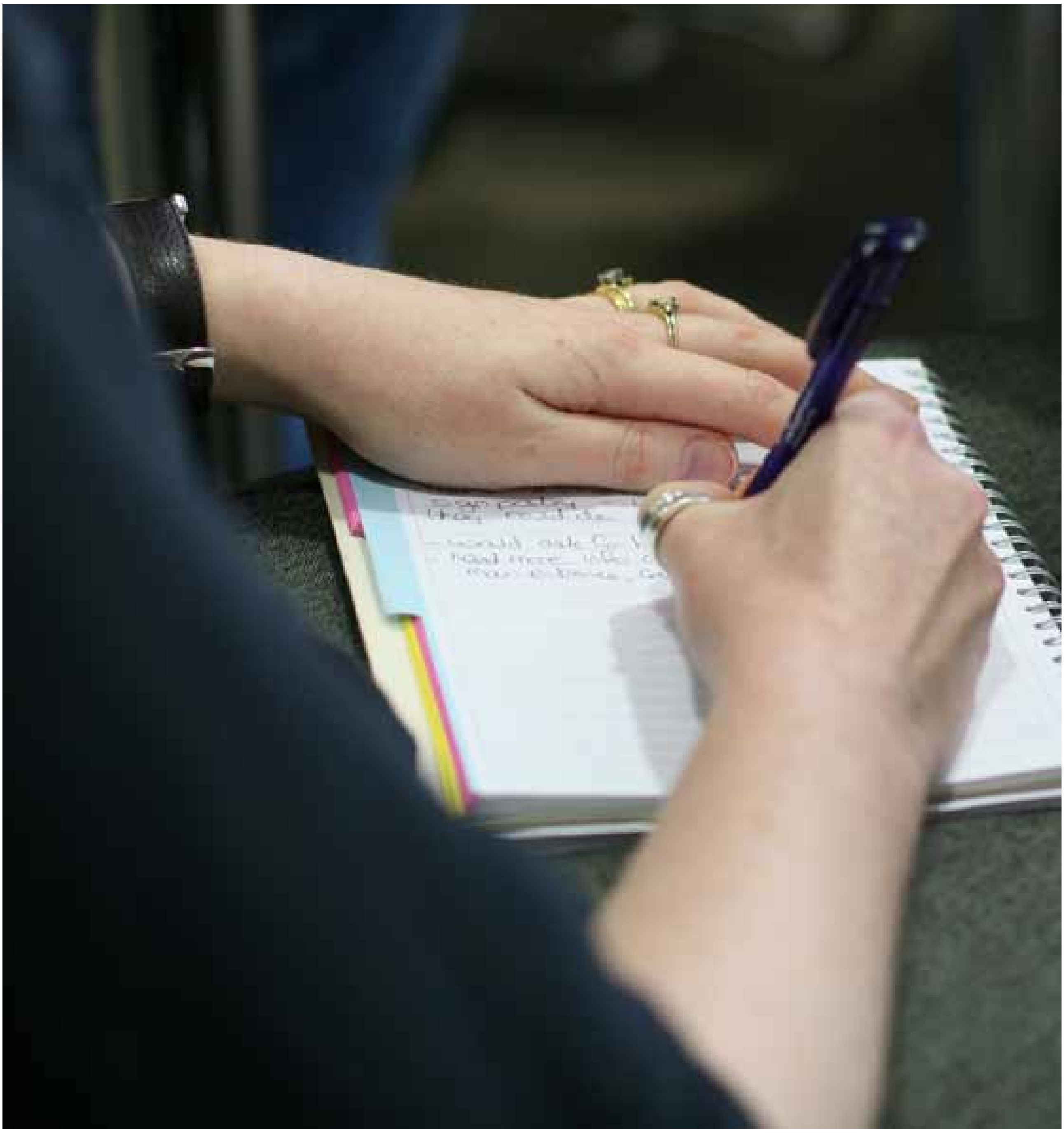
Despite the fact that PmPm models and worksheets were designed mainly to promote and enhance students' intuitive understanding of structural behaviour, they can actually bring a positive change to assessment as well. The prediction-validation routine of the worksheets, as well as the other guidelines promoting the use of PmPm in student peer-to-peer presentations, allow assessment of other attributes beyond the understanding of structural mechanics, such as reviewing and checking the work of others and providing effective feedback. This attribute, in addition to being able to communicate a concept effectively, can only be mastered with very good knowledge of the subject, thus an assessment activity that combines all of the above gives students a richer experience – a rare phenomenon in the compartmentalised module system used in higher education institutions. Equally importantly, it provides the academic with a larger pool of assessment metrics to evaluate student participation and increase understanding.

Had staff relocations not taken place, group members would have visited more universities to introduce PmPm. However, this change allowed the group to consider creative alternatives and seek other paths of communication, such as the Expedition Workshed blog and social networks, to disseminate the outcomes of this project. The feedback received to date from academics and students is positive and promising. Furthermore, this project, which started as an industry initiative, has created a collaborative network as a synergy between industry and academia to confront one of the problems in the teaching of structural analysis in civil engineering courses. It is anticipated that the successful collaboration model for creating an interactive teaching tool could be easily transferred to other STEM subjects.

PmPm and the Workshed have been praised for their innovative approach to engineering education by many leading figures in the field.

Following initiation of this project, EE has also progressed to expand the set of interactive tools on the Expedition Workshed website by creating a 2D qualitative structural analysis engine that allows the user to create node-element structures and load them to collapse, as well as a 3D engine that has even greater capabilities. These developments directly address feedback from the questionnaire. This opens the door to academics and institutions who are interested in the teaching of structural analysis to create their own structural models and share them on the Expedition Workshed, informing the rest of the community about new developments through the Workshed blog. In this way, the Workshed could become a dynamic hub of free, accessible "bolt-ons" that lecturers could use to showcase their work in enhancing the learning experience of their students and share examples of best practice.

The full case study and literature references can be found at: **www.hestem.ac.uk/sites/default/files/push_me-pull_me_0.pdf**



Appendix

Development and implementation of teaching aids to enhance the understanding of control systems
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Engaging employers and schools to support and facilitate the promotion of civil engineering courses among female students
Professor Amir **Alani**
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Safety engineering programme: a partnership development between academics, engineering practitioners and professional institutions
Professor Amir **Alani**
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Industrial lectures for level 4 electrical and electronic engineering students
Matthew **Armstrong** and Sarah Olsen
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Dr Kerry Jaine **Baker** and Dr Nazira Karodia
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Developing Employer Engagement in STEM through Career Mentoring
Annette **Baxter** and Dr Jeff Waldock
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Higher (University) Apprenticeships in engineering technology: SME employer model
Rao **Bhamidimarri** and Anthony Roberts
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The development of a small-scale geotechnical teaching centrifuge
Jonathan **Black**, Sam Clarke
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Designing the Future – engineering education colloquia series
Denise **Bower**, Nancy Madter, George Hagan
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J. R. **Bradley** and J. Crowther
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Bob **Cater** and Rebecca Griffiths
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Keystage two engineering outreach project

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Understanding student perspectives on the transition from university to work

Martyn **Clark** and Anthea Connolly

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Model for engaging women within BME populations into HE engineering programmes in East Lancashire

Melissa **Conlon**

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Enhanced employer engagement with work-based learning (WBL) modules in engineering foundation degrees

Gavin L. **Cutler**

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Using part-time students as mentors

John W **Davies**

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Cognitive apprenticeship meets industrial apprenticeship

John **Davies**, Tom Rogers, Steve Austin and Jon Ordidge

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Enhancing graduate employability skills through environmental consultancy experience

Steve **Dorney**

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What is engineering and an engineer?

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Using formative group projects with level 4 students to improve student attendance and promote student cohort cohesion

David **Dyke**

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Mr Andrew **Mallett** and Dr Sarah Fielding

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Development of engineering project management simulations in a virtual world to enhance students' engineering project management and employability skills

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Stylianos **Yiatros**, Lawrence Coates, Iain McLeod, Oliver Broadbent
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