Employer Engagement in Undergraduate Mathematics

Mathematical Sciences HE Curriculum Innovation Project

Edited by Jeff Waldock and Peter Rowlett

The Higher Education Academy Maths, Stats & OR Network

National HE STEM Programme

Employer Engagement in Undergraduate Mathematics

Edited by Jeff Waldock and Peter Rowlett

July 2012

The Higher Education Academy Maths, Stats & OR Network

National HE STEM Programme

Contents

Introduction **5**

1. Industrial Problem Solving for Higher Education Mathematics **23**

2. Industrial problems in statistics for the HE curriculum **27**

3. A Statistical Awareness Curriculum for STEM Employees **33**

4. Assessing student teams developing mathematical models applied to business and industrial mathematics **41**

5. How realistic is work-related learning, and how realistic should it be? **47**

6. Models of Industrial Placements for Mathematics Undergraduates **53**

7. Supporting progression in mathematics education **63**

8. Being a Professional Mathematician **67**

9. Graduates' Views on the Undergraduate Mathematics Curriculum – summary of findings **71**

Introduction

By ‘employer engagement’, we include various activities which involve employers, employees or professional bodies in a number of aspects of curricula and extra-curricular undergraduate activity. This booklet primarily reports on nine projects relating to employer engagement supported by the Maths, Stats and OR Network (MSOR) as part of the National HE STEM Programme.

The HE Mathematics Curriculum Summit took place at the University of Birmingham on 12 January 2011 [1]. This brought together Heads of Mathematics or their representatives from 26 universities offering mathematics degrees (about half of those in England and Wales), representatives from the professional bodies, and others. One outcome of the Summit was a series of recommendations [2]; four of these relate to employer engagement and have led to five projects reported in this booklet (Projects 1, 2, 6, 8 and 9).

In addition, four projects addressing the area of employer engagement were supported through general funding and are reported in this booklet (Projects 3, 4, 5 and 7).

All nine projects had completed their MSOR-supported activity by the end of July 2012, and this publication presents the final reports of each together with a commentary which aims both to contextualise and to summarise the outcomes, providing a record that is of value to the community. Relevant National HE STEM Programme projects not supported through MSOR will also be summarised in this introduction where appropriate. Hopefully this will prove right the adage that the whole is more than the sum of the parts!

Employer Engagement

In gathering together the outputs of these projects, it is important to recognise that the broad area of employer engagement covers many separate but related activities. It is perhaps helpful to categorise these into the following themes:

1. **Curriculum Design and Delivery** – including:
   a) Employer views of the relevance of curriculum content and design
   b) Industrial placements, and other forms of work-based learning (WBL)
   c) Provision of ‘real world’ problems, and other forms of work-related learning (WRL)
2. **Research and Consultancy** – in which HEIs provide expertise to industry. A sub-category is:
   a) Provision of training for workforce development and CPD. Universities can provide taught bespoke award-bearing courses (sometimes in-house) for specific industries.
3. **Careers Awareness and Guidance** – through for example role models, case studies and mentors.

These principally benefit universities, industry and students respectively; however in each case there are different yet significant benefits to each partner, the various forms of partnership forming a mutually beneficial ecosystem. The discussion section, starting on page 9, will therefore be structured around these three broad themes.

Context

For many UK higher education institutions, employer engagement has increasingly become a core part of the academic culture. For some, their goal has always been to provide graduates ready for the workplace; for others a key focus has been the research income derived from business and industrial links. Other forms of employer engagement include in-company training programmes, industry-designed courses and student placements and internships.

In recent years there has been a growth of whole curriculum-based approaches to developing graduate employability, and a rapid growth in enterprise education and entrepreneurship amongst the student body. Foundation degrees, providing qualifications with content closely defined by employers and building in workplace experience, have grown from 4,300 enrolments in 2001 to 103,000 by 2010 ([3], p. 21).

The enhancement of employability skills has been a constant target of funding interventions from Enterprise in Higher Education (EHE) in the 1990s, and subsequently through the Fund for the Development of Teaching and Learning (FDTL) and the Teaching Quality Enhancement Fund (TQEF). Recent funding initiatives included the 74 Centres for Excellence in Teaching and Learning (2005-10), 22 of which were focussed on employability and employer engagement, and those managed through the various subject centres of the Higher Education Academy. In Mathematical Sciences, funding for this work was through the Maths, Stats and Operational Research (MSOR) subject centre (2000-2012), and latterly the National HE STEM Programme (2010-12).

The 2006 'Leitch Review of Skills' [4] shifted the emphasis away from the broad employability of graduates towards specific workforce skills and included targets for workforce participation in HE through to 2020, noting that the supply of graduates from the traditional 18 to 21 year cohort would be insufficient to meet the country's high-level skills needs. A substantial proportion of the 2020 workforce has already left compulsory education, so those in employment should be a focus for up-skilling. Leitch also recommended joint funding for this education with employers contributing more, since they would benefit from a more highly skilled workforce.

As part of the government's response to the Leitch review, HEFCE were asked by the Government "*to develop a new funding model that is co-financed with employers, achieves sustained growth in employer-based student places and introduces the principle of employer demand-led funding*" ([5], p. 50). A Workforce Development Programme invested around £150 million over 2008-2011 in universities to develop their operations with employers around a new co-funding model ([6], p. 17).

The implementation of the reforms detailed in the 2011 White Paper 'Students at the Heart of the System' [7] will have a significant impact upon business–university collaboration. A key aspect of the reforms is a shift from government grants to universities being primarily funded via student loans. The employment expectations of fee-paying students, coupled with enhanced information on course outcomes, is expected to encourage universities to promote student employability and better support their transition into graduate employment.

All stakeholders in Higher Education are increasingly aware of the importance attached to the additional skills students should be gaining at University, over and above their course-specific skills. Students are concerned, particularly with the large rises in tuition fees, whether courses will provide them with the full range of skills necessary to successfully gain graduate level employment. It is clear, particularly from University open days, that prospective applicants are very aware of the new measures by which they can judge the performance both of Universities and of individual programmes, such as the National Student Survey, the Destination for Leavers from Higher Education survey of graduate employment, the Key Information Sets and the various league tables, as published for example by the Guardian and the Times.

In what is certain to be a very competitive student recruitment 'marketplace' there will be considerable importance attached by each university and by each course to presenting a successful profile by each of these measures. This is especially true at a time of high levels of graduate unemployment. The Guardian, for example, recently reported that "*20% of recent graduates are unemployed – the highest proportion for a decade* [8] and "*Almost half of all recent graduates believe their university education did not adequately equip them for the world of work*" [9].

External Influences

Employer engagement has been encouraged by **the government** both before and after the 2010 General Election:

> *"We will bring together universities, employers, HEFCE and the UK Commission for Employment and Skills (UKCES) to identify and tackle specific areas where university supply is not meeting demand for key skills, and will expect all universities to describe how they enhance students' employability"*
>
> *"it is a top concern for business that students should leave university better equipped with a wider range of employability skills."*
>
> *"All universities should be expected to demonstrate how their institution prepares its students for employment, including through training in modern workplace skills such as team working, business awareness, and communication skills"*
>
> "Higher Ambitions", 2009 ([10], p. 8)
>
> *"Our expectations of business will continue to rise: they need to be active partners with universities, not passive customers."*
>
> *"The majority of businesses that invest in high level skills do not make enough use of higher education. This should change: businesses should tap the resources available in universities more effectively, and universities should become more flexible in providing for business demand."*
>
> "Higher Ambitions", 2009 ([10], p. 9)
>
> *"Universities should develop proposals to integrate a flexible element of professional experience into all higher education courses"*
>
> "Unleashing Aspiration", 2009 ([11], p.97)
>
> *"We are committed to opening up the higher education market, including to further education colleges and alternative providers, to meet the changing needs of employers, individuals and their communities."*
>
> "Students at the Heart of the System", 2011 ([7], p. 10)
>
> *"The evidence suggests that having work experience or an internship on a CV is even more critical to finding employment now than it was even three years ago. Over one-third of this year's graduate vacancies will be filled by applicants who have already worked for the employer as an undergraduate and, in some sectors, the proportion increases to 50% or more. The critical questions are who gets these opportunities and how do they get them"*
>
> "Fair Access to Professional Careers", Alan Milburn, 2012 ([12], p. 21)

Employer engagement has also been encouraged by the **student body**:

> "[Universities should] *increase resources for, and promote the use of, personal development plans, and provide optional modules/classes that consider how the skills and knowledge are developed"*
>
> *"We would like ... a clear university-wide employability strategy"*
>
> *"We would like ... a high quality, well-structured work experience programme"*
>
> "National Student Forum, Annual Report", 2009 ([13], p. 7)

Employers have also emphasised the need for further engagement with Universities, particularly emphasising the importance of work experience – especially a placement year:

> *“Universities should work more with employers to develop the curriculum in a way which embeds employability skills into every degree course”*
>
> *“Some vocational degrees already incorporate industry placements but they should be incorporated in many more courses.”*

“A Manifesto for Graduate Recruitment”, 2010 ([14], p. 5)

A 2011 CBI report “Building for Growth, Business Priorities for Education and Skills” [15] finds that STEM skills are in demand at every level, but employers face difficulty in finding staff. STEM applicants are not meeting business needs, but it is recognised that science and maths hold the key to STEM progression.

Further stimulation for closer links between Universities and employers was provided in 2012 by the Wilson Review of Business-University Collaboration [3]:

> Recommendation 3, paragraph 4.5.1: *“Sandwich degrees should be encouraged through a new compact between students, universities, government and employers”*
>
> Recommendation 4, paragraph 4.5.2: *“Every full-time undergraduate student should have the opportunity to experience a structured, university-approved undergraduate internship during their period of study”*

In order to enhance graduate skill levels and to ensure a smooth and effective transition between university and business environments, there is a need to increase opportunities for students to acquire relevant work experience during their studies. Sandwich degree programmes, internships and work-based programmes all have roles to play in achieving this.

In many ways, liaison between Universities and business can be an uneasy alliance. There has to be a real benefit accruing from the partnership for both – government pressure to collaborate is not enough. Employers are quite right when they ask “what’s in it for me?” The various forms of employer engagement, as stated in the introduction, can be essentially categorised into those that benefit universities, those that benefit employers and those that benefit students – while recognising that in some cases, benefits to all may exist simultaneously.

Discussion

A STEM-wide review of employability skills has been carried out by Adrian Toland on behalf of the National HE STEM Programme [16] which discusses principles of effective employer engagement, and makes a number of recommendations for improving graduate employability in general and developing an enhanced capacity for employer engagement in particular. Much good practice, from 12 case studies, has also been identified by the Practice Transfer Partnership '*Employer Engagement in Mathematics*' led by Edmund Chadwick [34].

Many of the issues that have arisen in the course of each of the projects reported on in this booklet have been addressed, at least in part, by Tallantyre and Kettle in their 2011 publication '*Learning from Experience in Employer Engagement*' [17]. In this work, the key focus was on engaging all stakeholders in the process, focussing on practical as well as pedagogical issues. The authors are reporting on the outcomes of projects funded by the HEA from 2008, and although the work is not discipline-specific, there are a number of important lessons that they draw out, including how to help university staff develop new ways of working, how to make learning accessible to adults in employment and how to create new curricula and awards.

The importance of employer engagement in Mathematical Sciences was highlighted by the recommendations from the HE Mathematics Curriculum Summit [1].

Curriculum Design and Delivery

In the work described in this booklet, there is a clear presumption that academic staff recognise the importance of making their programmes relevant to business and industry. It raises the very important question of what exactly a degree should comprise at a time when the student is paying for their own tuition; however that is beyond the scope of this booklet!

A fundamental role of university academic staff is to design and deliver the academic curriculum. Furthermore, a mathematics degree programme should take account of the requirements of the QAA benchmark statement [18] and will be approved through institutional quality assurance procedures. This is a non-negotiable situation; the university is accountable for the standards of its awards and the quality of its provision. Programme approval by the Institute of Mathematics and its Applications, providing it is followed by suitable training and experience, entitles a graduate who is a Fellow or Member of the IMA to apply for chartered mathematician status. This approval, however, requires that two thirds of the topics on the course are mathematical, constraining the freedom of academic staff to design the degree programme. Although these requirements may appear to limit the freedom of employers to further influence the curriculum, experience indicates that there is sufficient common ground between employer needs, QAA benchmarks and IMA requirements for there to be little reason why employer needs, at the discretion of the university, cannot be integrated within the mathematics curriculum, if necessary through the creative use of learning, teaching and assessment strategies.

When designing a programme of study, academic staff must first articulate the type of graduate they are aiming for – which leads formally to a set of programme learning outcomes. In order to determine these learning outcomes, the views of the relevant stakeholders must be sought. These include relevant employers – some of whom may be alumni of the department – who can advise on what skills they have found useful in their career so far.

Industrial Advisory Groups

Increasingly there has been a desire to develop close links with employers through the creation of advisory groups, often referred to as Industrial Advisory Boards (Messmer [35], Good [36], Singh-Calay [37], Singh [38], Singh [19]). These groups may act as 'critical friends', monitoring the activities and development of the department; others act as industry advisors in research fields and in curriculum design. The Wilson Review [3] made a specific recommendation to this effect:

> *"Universities that work with employers through industry advisory groups should consider including the existence of such a group, its membership and its influence, within the university's enterprise strategy and within the material that it provides to applicants and students."* Reflective recommendation 10, paragraph 4.6.1

Adrian Toland [16] also suggested that universities should "*Create employer forums that allow industry to contribute directly to the development of curricula and bring industrialists into HEIs to support teaching*".

1(a) Collecting the views of employers

HE Mathematics Curriculum Summit Recommendation 14: *Research to collect the feedback of graduates in employment on the mathematics HE curriculum [1].*

A first approach to incorporating employer input into the curriculum at the design stage is to find out what skills and qualities they would like to see in a graduate from the programme. This will help inform the design of the programme learning outcomes; a subsequent step would be to design the curriculum, and the associated learning, teaching and assessment strategy, which will deliver these outcomes.

Inglis, Croft and Matthews (Project 9) surveyed 428 mathematics graduates two years after graduation on the skills they gained in their degree and how useful they had been in their career so far. Results were that the vast majority recognised that their degree provided them with useful cognitive skills, but that the highly valued non-cognitive skills which incoming undergraduates expected to develop, such as making presentations, oral and written communication and team working, were missing. When asked what skill graduates wished they had had the opportunity to develop more during their mathematical studies, the most commonly selected was "applying mathematics to the real world". Over 90% of incoming undergraduates expected to develop this skill, whereas only around 60% of graduates believed that they had.

Although not its primary aim, Project 3 worked to collect the views of employers and develop a list of employer expectations of the statistical knowledge, awareness and skills of STEM graduates. A number of other projects gathered information from employers and graduates in employment about what skills should be built into a mathematics degree, including Hind [39], Messmer [35], Bradshaw [40], Levesley [41] , Cooper ([42], [43]) and Golden ([20], case study 11).

Collecting the views of students

Of equal importance is the view of current students. This includes the expectations of students before starting a degree and, since the ability to recognise the skills that a degree provides is important, the views of students currently studying for a degree. Hind [39] surveyed student views and Cooper has reported a project which developed a student-led employability audit toolkit [42]. Student and graduate awareness of the skills they develop at university was explicitly addressed by Bradshaw [44] and by Chatwin [45].

1(b) Industrial placements, and other forms of work-based learning (WBL)

Work experience can make a significant difference to a student's chances of gaining graduate level employment. There is strong evidence to indicate that authentic work experience contextualises learning, has a strong influence on graduate employment and should be integrated into course curricula wherever possible [21]. The Wilson review [3] went as far as to state that the "*lack of work experience appears as a key barrier to young people, including graduates, in securing employment*". It also points out that there has been a decline in this practice in recent years from 9.5% of the total full-time cohort in 2002/2003 to 7.2% in 2009/2010 and that in the UK most sandwich placements are provided by a small number of universities. Furthermore, as is discussed by Tony Mann (Project 6) even when a placement programme is available, it is often the case that only a small proportion of students take advantage of the opportunity.

Barriers to the take-up of sandwich provision include the time pressures of application, uncertainty in securing a placement, strong peer group pressure to opt out, and difficulties in finding a placement close to the university or parents' home. Despite this, some universities can still succeed in getting a significant proportion of sandwich students placed, suggesting that sustaining a sandwich course structure may be a consequence of university culture, strategy and investment and course portfolio. Aston University, for example, aims to have all students undertaking a placement year by 2020 [22]. With the increase from 2012 in tuition fees, a number of universities have included a fee waiver for the placement year, providing an additional incentive for students to apply for a sandwich degree. Research evidence (e.g. [23]) suggests that students taking a placement year gain a better degree, although it is likely that it is the better students who are more likely to get a placement in the first place.

Clearly, universities have to invest to provide placement opportunities for students and developing and maintaining relationships with employers is not cost free. Good experiences however lead to repeat placements at a lower cost, and can deliver collaboration in other areas of university services. It is in the interests of students, employers, universities and government that barriers to increasing the number of students benefiting from sandwich placements are removed.

If graduate employability is of importance to course designers, it seems clear that the curriculum should embrace some form of work based, or work related, learning. There are a number of models to follow – and not all require a full sandwich year. There is clearly much to be gained from helping students recognise, and articulate, the skills they gain from all forms of work, including voluntary and casual work. Many universities now operate a skills award which recognises this, but it is possible for the course curriculum to also incorporate explicit recognition of the skills acquired in the workplace, wherever that may be.

HE Mathematics Curriculum Summit Recommendation 6: *Pilot of undergraduate students gaining experience of working in industry through short term placements (e.g. 2 hours per week) [1].*

Partly in response to this recommendation, Tony Mann (Project 6) has reviewed current models of industrial placements for mathematics undergraduates, finding three basic models of delivery:

1. Sandwich placements, usually lasting 12 months, between the second and final year of study. The proportion of the year group taking a placement of this kind is typically quite small however.
2. Placements in schools and colleges, either via the Undergraduate Ambassador Scheme or by other means. James Hind (Project 7) reports results of a project that involved undergraduate students observing, preparing and delivering material to GCSE and A-level classes. Although not a full year placement, the students involved gained valuable school and classroom experience.

   A related project led by Karen Ayres at the University of Reading [24] involves undergraduates undertaking small, paid, learning and teaching projects to create curricular materials for use on their course.
3. Short term work placements, such as vacation internships or via a credit bearing final year module. These are usually unpaid. Some examples of such internships have been reported from **sigma**-sw ([25], [26]), related to the ***HE Mathematics Curriculum Summit Recommendation 13:*** *Fund undergraduate students to undertake focused summer intern projects within universities* [1].

In general, employers are likely to prefer the year long placement as students can be trained to fulfil a more specific role and it gives time to get a sufficient return on this investment. The student is also more likely to gain technical, professional and workplace skills.

The learning that takes place as a result of an industrial placement can extend beyond the end of the placement itself. There are a number of programmes which incorporate a final year module in which students reflect on the learning from placement. The project led by Tony Mann (Project 6) included the development of a 30 credit final year 'Mathematics Industry Placement' module, for example.

The effectiveness of industrial placements cannot be taken for granted. As discussed by Chatwin [45], it is clearly necessary to introduce institution-wide mechanisms for evaluating all aspects of placement activity including the sourcing and monitoring of placements and the support provided to students while on placement.

1(c) Provision of 'real world' problems – and other forms of work-related learning (WRL)

In a review of HE STEM Employability Skills, on behalf of the National HE STEM Programme, Adrian Toland [16] echoes the importance of work experience, and points out that with the availability of industrial placements becoming more limited, alternative mechanisms for students to gain indirect experience of industry are of importance. These include industrial simulation, project-based learning, industrial group projects, case-studies from industry, site visits and field trips, the influence of part-time and mature students, entry to competitions and student involvement with professional institutions.

Many programmes are developing elements of work-related learning to complement or act as a substitute for work-based learning. This has led to ***HE Mathematics Curriculum Summit Recommendation 4:*** *Develop a bank of industry-based problems, suitable for undergraduate students, developed in consultation with industry partners and vetted* [1].

Two projects were funded in response to this recommendation and summary reports have been included in this booklet. The first is "Industrial Problem Solving for Higher Education Mathematics", Benjamin et al. (Project 1) and reports the creation of an on-line resource, IPSHE, which makes available to the community a repository of real, documented, industrial problems categorised as introductory, intermediate or advanced, corresponding approximately to the three years of undergraduate study. There are currently about 60 problems in the repository.

The second funded project is "Industrial Problems in Statistics for the HE Curriculum", Davies and Marriott (Project 2). This provides a freely available web-based repository of problems, with relevant data, in one particular industrial area. Access to solutions of the problems are available by email on request.

Project 5 included in this booklet, from Edmund Chadwick (Salford) raises a question about the degree of realism that work related learning should exhibit. It summarises the outcomes of a workshop held on 7th March 2012, involving input from universities and professional bodies, emphasising that for real learning to take place, work-related learning must be authentic. It recognises however that institutional constraints will limit the degree to which authenticity can be achieved.

Curricular strategies to develop realistic workplace skills, particularly inter-disciplinary team working skills and enterprise, are rare but one approach is an innovation at Sheffield Hallam University called the Venture Matrix ([20], case study 5). This involves teams of students forming 'ventures', each offering a service or a project. Project ideas can also come from external organisations, in which case these are 'live' rather than simulated projects. The ventures offering services pitch to work on one of the projects, and if successful, work together to deliver the service or product. The work contributes to validated modules, so is credit bearing and is assessed. Over 1500 students took part in the 2011/12 session.

A number of projects are developing specific modules that provide work-related learning through student engagement with 'real world' activities:

- Project 4 in this booklet, led by Edmund Chadwick, describes a module delivered to mathematics undergraduates at Salford in which they work in groups to solve employer-defined problems. The industrial partners are also involved in the assessment of the student work, and a key lesson was that employer involvement is paramount for success. Students valued the employer feedback, feeling that this made the module content real and relevant.
- The project led by Margit Messmer at Leeds [35] worked with key employers to develop such real world learning activities. These are to be incorporated into a second year module 'Maths at Work' in which students work in groups, developing team working skills, on a variety of industrially-related problems.
- At Leicester the mathematics programme includes an optional second year module 'Business Applications of Mathematics' which requires students to work on four case studies based on real life business problems ([20], case study 16). Students also reflect on the transferable skills they are developing whilst working through the case studies and are encouraged to consider how they can evidence these in the recruitment and selection process for graduate employment. The programme also now includes an employment based project module, developed as part of the HE STEM project [41].
- In a similar way, Good [36] is developing a 10-credit 'Mathematics in Industry' module for second year undergraduates at Birmingham.

Sarah Chatwin [45] also uses local employers to provide 'real world' experiential learning tasks, and produces materials for employers to explain the benefits for them in getting involved in the HE mathematics curriculum.

Vivien Easson [46] brought together employers and academic staff to make specific links between the HE curriculum and 'real world' applications, following on from materials developed at QMC for the More Maths Grads projects, such as the booklet 'Where the maths you learn is used'.

Research and Consultancy

This area of employer engagement is largely outside the scope of this booklet, which has its main focus on the undergraduate curriculum, however the idea of industrial study groups has been the subject of one of the outcomes of the HE Mathematics Curriculum Summit, on which theme some work has taken place.

HE Mathematics Curriculum Summit Recommendation 5: *Pilot extending the model of the 'study groups with industry' to undergraduate project work* [1].

Study groups with industry were first set up at Oxford University over 40 years ago, with the idea of providing a forum for industrial scientists to work with academic mathematicians on industrial problems. The study groups have continued through the European Consortium for Mathematics in Industry (ECMI), and take the form of an intensive week-long event, with participants working on a collection of problems provided by the industrial partners. There are clear benefits to all involved, as described at www.maths-in-industry.org.

In the past, the academic participants in these study groups have been staff and postgraduate students. O'Brien et al., [27] discussed ways in which this concept might be extended to undergraduate students, and the benefits this could bring.

The project led by Sarah Chatwin at Bath [45] included the development and implementation of a model of "Industrial Study Group" employer-led problem-based learning that is embedded within the curriculum for undergraduate students across several STEM disciplines.

2(a) Provision of training for workforce development and CPD.

Following the Leitch review, in 2006, there have been a number of initiatives introduced in response to the perceived need to upskill the workforce. The National HE STEM Programme identified workforce development as one of its themes, and there have been 173 projects funded (123 listed under Mathematics), which are linked in some way to this theme. (See www.hestem.ac.uk/activity/workforce-development.)

Workforce development was not a central theme of this booklet, however Project 3 - A Statistical Awareness Curriculum for STEM Employees (Neville Davies and John Marriott) - is clearly focussed on developing workplace statistical skills. The project is aimed both at STEM employers and employees, developing employer awareness of the role of statistical skills, and the need for auditing their workforce in this respect. A web-based tool for carrying out this audit is created. Based on research, a set of statistical skills that STEM employees should be expected to be able to demonstrate is presented.

There are several other National HE STEM Programme projects that are relevant, although some overlap with other themes:

"Enhancing workplace statistical literacy by work-based learning", (Paul Hewson, Plymouth [47]) aims to increase the confidence of a wide range of employees in using statistics in their day to day work.

"Workforce mathematics course", (James Hind, Nottingham Trent, [39]), gathers input from employers and students who have joined the workforce to formulate an improved skills programme to run within the Mathematics department.

"An interactive, online numeracy resource for pre-registration student nurses and midwives", (Sarah Green, University of the West of England [48]), uses an e-assessment system to enable students to self-assess their level of numeracy. It also provides a virtual patient whereby medicine management, in the guise of numeracy, will be directly applied to the clinical environment and patient safety.

"Mathematics support in the National Health Service", (Lynda Gatecliffe, Bradford [49]), applies the learning gained by universities in their provision of 'mathematics support' to students of all backgrounds and abilities to assist those within the workplace to develop their mathematical skills.

Other recent workforce initiatives include the validation of awards by universities that are designed for a particular employer. These are often postgraduate specialist awards, but there are examples of undergraduate sub-degree level awards that have been created. Some of these are taught within the workplace. There is no evidence of this happening yet in Mathematical Sciences however; current examples have tended to be in areas of business, finance and marketing ([28], [29]) but it is something perhaps to be aware of.

Careers Awareness and Guidance

From the student perspective, a vital thread of employer engagement is through the provision of possible career paths. While some subjects are clearly vocational, with a self-evident career path, this is not the case for Mathematics. Statistically, a high proportion of maths graduates enter the general area of finance – although this itself covers a very wide area, including accountancy, banking, investment, credit risk, actuarial work and insurance – but there are maths graduates entering almost every profession. Apart from the significant minority who intend to teach, most maths undergraduates do not have a clear idea of their career path.

An important part of graduate employability is being prepared to enter the world of work and being able to successfully apply for and gain graduate employment. It is also about developing your career beyond that, throughout your working life. If the HE mathematics curriculum is to provide such graduates it must incorporate activities that will develop these skills.

One such skill is careers awareness. Employers can provide help in several ways – for example by providing role models, offering visits and giving presentations. The provision of work based, or work related, learning opportunities – as discussed earlier – will also clearly help. One successful approach is through Career Mentoring, in which a student mentee is paired with a mentor in employment, ideally a graduate of the student's course. The mentor provides the student with one to one guidance on all aspects of career planning, helping them to develop the necessary understanding of a particular industry, and advice on how to successfully gain employment within it. A scheme of this type in Mathematics at Sheffield Hallam University has been funded through the National HE STEM Programme [30]. A student taking part in the scheme said "*I have learned that I am more confident than I thought [and] I felt my communicating skills, face to face, have improved greatly as a result of the scheme*".

As part of the increased awareness of the importance of graduate employability, many universities are incorporating Career Management Skills (CMS) into the HE curriculum. These include the more practical aspects of job application, including recognising how to articulate and evidence your own skills in order to produce a good CV and to perform well in interviews.

> *'The CMS modules provide fantastic opportunities for students to develop extremely useful and practical skills that employers consistently look for in the recruitment and selection of candidates. I have found that units significantly support development of transferrable skills in leadership, teamwork and planning and organising which are essential within graduate recruitment.'*
>
> Fiona Bousfield, Senior Officer, Attraction – Graduate Recruitment, Teach First [31]

A review of different approaches to the incorporation into the curriculum of CMS has been published by Evans [32].

Discussion at the HE Mathematics Curriculum Summit focussed on the need to build an understanding of the development and culture of the subject:

HE Mathematics Curriculum Summit Recommendation 3: *Develop a collection of teaching resources on the development of mathematics - stories from history and more recent development of the discipline. These should aim to counter a view of mathematics as a static, completed body of knowledge and instead encourage awareness of the process of doing mathematics. They should develop students' awareness of the culture of mathematics* [1].

In response to this, Tony Mann and Chris Good were funded to create materials on 'Being a Professional Mathematician' (Project 8). Audio interviews were recorded with eight contemporary mathematicians, working in various fields, and with five historians who described the work of important mathematicians in the past. These emphasised the types of skills required in the workplace and the important of networking in professional practice. Teaching materials were produced that could be used as a basis for tutorial activities, and made available at www.beingamathematician.org.

The National HE STEM Programme project led by Margit Messmer at Leeds [35] included a series of employer-led events held in the School of Mathematics and promoted as "November is Careers Month". Attendance, however, was poor with students appearing not to be interested in attending such co-curricular activities. Feedback indicated that the timing of these events was crucial, and - interestingly - that all activities should form part of the taught curriculum. The second year module 'Maths at Work' is to be introduced in 2012/13 and will incorporate career development activities, with employer input. A series of video interviews with students returning from work placement were made to increase awareness of possible career paths for mathematics graduates and to motivate school students.

The Mathematics staff at the University of Greenwich have been involved in a number of National HE STEM Programme and MSOR-supported projects in recent years. Two projects have been particularly successful in engaging students with employers, justifying an extended review.

Noel-Ann Bradshaw [44] has led a project working with the Adab Trust, a charity which focuses on improving the prospects of black minority ethnic (BME) graduates. This involved a combination of events for students and training sessions for staff, with the focus on sustainability. Academic staff attended the student events and training sessions so that they will be able to deliver similar employability events themselves in the future. The overall aim was to make maths graduates more employable, through the delivery of master classes and workshops which helped them become better able to recognise their skills. Tony Mann supplied the following text.

> *"We ran a series of masterclasses with very senior staff from major companies such as State Street Bank and Quintain Estates (a large local employer) together with workshops and CV clinics. Students engaged once they realised that these events had been tailored to their specific needs. We came to realise just how demoralised our students felt about their employment opportunities in the current financial climate. Fear of failure to achieve a desirable job was leading students to behave like ostriches burying their heads in the sand, doing nothing rather than taking the positive action that would help them succeed in the graduate marketplace. Staff saw students gain in confidence as the series developed, and found that more students were engaging with the application process. The training events for staff were well attended and, as well as giving insights into ways to engage and help students, provided opportunities for discussion of future strategy mediated by experts in the specific employability needs of our students.*
>
> *One factor which promoted student engagement was that staff were so prominent in their support of the events. Many staff attended the student workshops and this helped persuade students of the value of the activities. The project certainly helped build a stronger relationship between staff and students, and left staff with a much greater understanding both of the employment application process, and of the attitudes and fears of our students preparing to graduate and face an uncertain future in adverse economic conditions."*

Linked to this is a further project, also led by Noel-Ann Bradshaw [40] inviting Greenwich graduates in various industries to deliver talks and discuss their careers. Tony Mann supplied the following text.

> *"Ten recent graduates came back to the University to talk about their careers. The initiative was possible because tutors are in contact with many graduates through social networking: five years ago we would not have been able to organise an event like this. The graduates were carefully selected: we wanted to cover a wide range of careers to which students could aspire (including actuarial work, mathematical modelling, logistics, web technologies and teaching), to choose graduates to whom the students could relate easily, and to show that it isn't only the top undergraduates who can get desirable jobs. We chose outgoing, confident graduates who we knew would relate well to undergraduates.*
>
> *The outcome exceeded all our expectations. While previously the least confident students, who had most to gain from such events, had been reluctant to attend employability workshops and masterclasses, this event attracted a larger audience than any other we have organised, and generated enormous enthusiasm. There was a noticeable buzz amongst undergraduates over the next few days, many made personal contact with the graduates involved, and attendance at subsequent employability workshops was much higher. This seems to have been the 'breakthrough' event which encouraged nervous students to engage."*

With similar intentions, Chris Good [36] led a project explicitly aimed at sustainably embedding careers awareness as integral parts of the HE Mathematics curriculum at Birmingham.

Emma Nehemiah [50] has led a STEM-wide project establishing an industry-led programme of lectures for undergraduates across Wales during the first half of 2012.

Several case studies gathered through the booklet "*Developing Graduate Skills in HE Mathematics Programmes*" ([20], [33]) addressed the theme of careers awareness and guidance.

- Louise Walker described the practice of building CMS into the programme at Manchester through the maths-dedicated 'Calculating Careers' event ([20], case study 1);
- Jeff Waldock described the curricular strategies employed at Sheffield Hallam University to prepare second year undergraduates for applying for industrial placements ([20], case study 9);
- Kevin Golden and Guy Roberts described how the University of the West of England builds CMS into the curriculum through the Graduate Development Programme ([20], case study 11); and,

– David Graham and Annette Millar explain how the mathematics degree at Plymouth embeds careers awareness ([20], case study 17).

Summary

It is evident from the work reported in this booklet that the area of employer engagement is topical and relevant but complex. There is recognition on all sides that universities and employers have much to gain from closer collaboration and in an era of increased reliance for university funding on student tuition fees, the need to make curricula relevant, and graduates employable is becoming paramount. The work carried out through the many projects supported by the National HE STEM Programme, particularly those reported in this booklet, will play a major role in developing such curricula, and stimulate the further developments that will occur over the coming years.

Jeff Waldock[1] and Peter Rowlett[2]

July, 2012

[1]Department of Engineering and Mathematics, Sheffield Hallam University.

[2]Maths, Stats and OR Network, University of Birmingham.

References

1. Rowlett, P. (ed.), 2011. *HE Mathematics Curriculum Summit*. MSOR Network.
2. Rowlett, P., 2011. Acting on Recommendations from the HE Mathematics Curriculum Summit. *MSOR Connections*, 11 (3), pp. 4-7.
3. Wilson, T., 2012. *A Review of Business–University Collaboration* [The Wilson Review]. BIS. Available via: www.wilsonreview.co.uk/wilson-review/wilson-review.pdf.
4. HM Treasury, 2006. *Prosperity for all in the global economy - world class skills: Final report* [The Leitch Review of Skills]. The Stationery Office. Available via: www.hm-treasury.gov.uk/d/leitch_finalreport051206.pdf.
5. Department for Innovation, Universities & Skills, 2007. *World Class Skills: Implementing the Leitch Review of Skills in England*. The Stationery Office. Available via: www.bis.gov.uk/assets/biscore/corporate/migratedD/ec_group/37-07-Sk_b.
6. HEFCE, 2011. *Evaluation of the Higher Education Transforming Workforce Development Programme*. CFE. Available via: www.hefce.ac.uk/media/hefce/content/pubs/indirreports/2011/re1311workforcedevprog/rd13_11.pdf.
7. BIS, 2011. *Students at the Heart of the system*. The Stationery Office. Available via: c561635.r35.cf2.rackcdn.com/11-944-WP-students-at-heart.pdf.
8. Shepher, J., 2011. 20% of Graduates out of Work. *Guardian*, 26 Jan. Available via: www.guardian.co.uk/education/2011/jan/26/fifth-graduates-unemployed-ons.
9. Snowdon, G., 2011. Almost half of graduates ill-equipped for work. *Guardian*, 28 Jan. Available via: www.guardian.co.uk/money/2011/jan/28/half-graduates-ill-equipped-for-work#start-of-comments.
10. BIS, 2009. *Higher Ambitions: The Future of Universities in a Knowledge Economy*. Available via: www.bis.gov.uk/assets/biscore/corporate/docs/h/09-1452-higher-ambitions-summary.pdf
11. The Panel on Fair Access to the Professions, 2009. *Unleashing Aspiration: The Final Report of the Panel on Fair Access to the Professions*. Cabinet Office. Available via: www.cabinetoffice.gov.uk/media/227102/fair-access.pdf.
12. Milburn. A., 2012. *Fair Access to Professional Careers: A progress report by the Independent Reviewer on Social Mobility and Child Poverty*. Cabinet Office. Available via: www.cabinetoffice.gov.uk/sites/default/files/resources/IR_FairAccess_acc2.pdf.
13. National Student Forum, 2009. *National Student Forum Annual Report*. BIS. Available via: www.bis.gov.uk/assets/biscore/higher-education/docs/n/09-p83-national-student-forum-annual-report-09.
14. Association of Graduate Recruiters, 2010. *A Manifesto for Graduate Recruitment*. Available via: www.agr.org.uk/Content/AGR-A-manifesto-for-graduate-recruitment.
15. CBI, 2011. *Building for Growth: Business Priorities for Education and Skills*. Available via: www.cbi.org.uk/media/1051530/cbi__edi_education___skills_survey_2011.pdf.
16. Toland, A., 2011. *HE STEM Employability Skills Review*. National HE STEM Programme. Available via: www.hestem.ac.uk/sites/default/files/employability_skills_review.pdf.
17. Tallantyre, F. and Kettle, J. (eds.) 2011. *Learning from Experience in Employer Engagement*. HEA. Available via: www.heacademy.ac.uk/assets/documents/flexiblelearning/Learning_from_Experience_in_EE.pdf.
18. QAA, 2007. *Mathematics, statistics and operational research*. Available via: https://www.qaa.ac.uk/academicinfrastructure/benchmark/statements/Maths07.pdf.
19. Singh, M., 2011. London Metropolitan University Industrial Panel. *MSOR Connections*, 11 (3), p. 25.

20. Waldock, J. (ed.), 2011. *Developing Graduate Skills in HE Mathematics Programmes: Case Studies of Successful Practice*. MSOR Network.

21. Pegg, A., Waldock, J., Hendy-Isaac, S., and Lawton, R., 2012. *Pedagogy for Employability*. HEA. Available via: www.heacademy.ac.uk/assets/documents/employability/pedagogy_for_employability_update_2012.pdf.

22. Higson, H., 2012. How to Iimprove employability: Aston University's placements programme. *Guardian*, 29 Feb. Available via: www.guardian.co.uk/higher-education-network/blog/2012/feb/29/aston-university-student-placements.

23. Mendez, R. and Rona, A., 2010. The Relationship Between Industrial Placements and Final Degree Results: A Study of Engineering Placement Students. *Learning and Teaching in Higher Education*, Issue 4.2.

24. Ayres, L., Glaister, P. and Smith, C., 2012. The Benefits of an Undergraduate Teaching and Learning Placement Scheme in Mathematics and Statistics. *MSOR Connections*, 12 (1), pp. 2-6.

25. Taylor, M., Bond, O., Anderson, C. and Kennedy, A., 2012. Summer Internships in sigma-sw. *MSOR Connections*, 12 (1), pp. 23-27.

26. Cooper, B., Gillard, J., Graham, D., White J. and Wilson, R., 2011. Summer Internships in sigma-sw. *MSOR Connections*, 11 (3), pp. 13-14.

27. O'Brien, S., Mason, J., Charpin, J. and O'Sullivan, M., 2011. Student Mathematical Modelling Workshops as Preparation for Study Groups with Industry. *MSOR Connections*, 11 (3), pp. 8-9.

28. Coughlan, S., 2010. McDonald's to launch own degree. *BBC News*, 25 Nov. Available via: www.bbc.co.uk/news/education-11810930.

29. Tobin, L., 2010. Get a degree in sales from Harrods. *Guardian*, 21 June. Available via: www.guardian.co.uk/education/2010/jun/21/sales-degree-harrods-employer-led.

30. Baxter, A. and Waldock, J., 2012. Developing Employer Engagement in STEM through Career Mentoring. *In*: The Royal Academy of Engineering. *Enhancing Engineering Higher Education: Outputs of the National HE STEM Programme*. Available via: www.raeng.org.uk/news/publications/list/reports/Enhancing_Engineering_Higher_Education.pdf.

31. University of Manchester Careers Service, 2011. Careers Management Skills (CMS): What employers are saying. Available via: www.careers.manchester.ac.uk/media/services/careersandemployabilitydivision/careersservice/recruiters/Careers-Management-Skills.pdf.

32. Evans, C., 2008. Developing Career Management Skills within the HE Curriculum: a review and evaluation of different approaches. *International Journal of Management Education*, 6(3), pp. 45-55.

33. Waldock, J., 2011. Developing Graduate Skills in HE Mathematics Programmes. *MSOR Connections*, 11 (3), pp. 16-19.

National HE STEM Programme projects

34. Chadwick, E. *Practice Transfer Partnership – Employer Engagement in Mathematics*. Available via: www.hestem.ac.uk/activity/employer-engagement-mathematics.

35. Messmer, M. *Enhancing Employability by Engaging with Employers in Maths*. Available via: www.hestem.ac.uk/activity/enhancing-employability-engaging-employers-mathematics.

36. Good, C. *2020 vision: a curriculum for Mathematics graduates for the next decade*. Available via: www.hestem.ac.uk/activity/2020-vision-curriculum-mathematics.

37. Singh-Calay, P. *Industrial panel mathematics degree review*. Available via: www.hestem.ac.uk/activity/industrial-panel-mathematics-degree-review.

38. Singh. M. *Mathematics Industrial Advisory Board*. Available via: www.hestem.ac.uk/activity/mathematics-industrial-advisory-board.

39. Hind, J. *Workforce Mathematics Course*. Available via: www.hestem.ac.uk/activity/workforce-mathematics-course.

40. Bradshaw, N. *Greenwich Graduates – where are they now?* Available via: www.hestem.ac.uk/activity/maths-careers-greenwich-graduates.

41. Levesley, J. *Identifying skill gaps of employers and Mathematics undergraduates*. Available via: www.hestem.ac.uk/activity/identifying-skill-gaps-employers-and-mathematics-undergraduates.

42. Cooper. B. *Measuring the extent to which employability skills are embedded within existing degree programmes through a student-led employability audit*. Available via: www.hestem.ac.uk/activity/student-led-employability-skills-audit.

43. Cooper. B. *Developing a student-led employability audit toolkit for the HE STEM Curricula*. Available via: www.hestem.ac.uk/activity/developing-student-led-employability-audit-toolkit-he-stem-curricula.

44. Bradshaw, N. *Making Maths Graduates More Employable*. Available via: www.hestem.ac.uk/activity/making-maths-grads-more-employable.

45. Chatwin, S. *Strengthening, extending and embedding employer engagement*. Available via: www.hestem-sw.org.uk/project?id=46.

46. Easson, V. *Curriculum Impact – making explicit links to applications in business and industry*. Available via: www.hestem.ac.uk/activity/curriculum-impact-making-explicit-links-he-mathematics-curriculum-applications-science-tech.

47. Hewson, P. *Enhancing workplace statistical literacy by work-based learning*. Available via: www.hestem.ac.uk/activity/enhancing-workplace-statistical-literacy-work-based-learning.

48. Green, S. *An interactive, online numeracy resource for pre-registration student nurses and midwives*. Available via: www.hestem.ac.uk/activity/interactive-online-numeracy-resource-pre-registration-student-nurses-and-midwives.

49. Gatecliffe, L. *Mathematics support in the National Health Service*. Available via: www.hestem.ac.uk/activity/maths-support-NHS.

50. Nehemiah, E. *Regional industry lectures for STEM undergraduates*. Available via: www.hestem.ac.uk/activity/regional-industry-lectures.

(All web links last visited July 2012.)

1. Industrial Problem Solving for Higher Education Mathematics

Oscar Benjamin, **Martin Homer**, **Jonathan Lawry** and **Jonathan Rossiter**, Department of Engineering Mathematics, University of Bristol

Introduction

The Department of Engineering Mathematics has a long history of applied mathematics research in collaboration with both industrial and scientific partners, and has used its contacts and experience to accumulate a body of real research problems suitable for undergraduate students. The Industrial Problem Solving for Higher Education project (IPSHE) creates a shared resource to be used in providing training and experience in the application of mathematical techniques to real industrial and scientific problems.

Our department has a long-standing teaching methodology that emphasises experience with real research problems in every year of undergraduate education to develop transferrable skills in addition to technical ones. Complementing the traditional programme of mathematical study, our students are encouraged to develop skills in communication, project planning, group work and general research. The IPSHE project is intended to facilitate and promote the adoption of similar teaching paradigms at other higher education institutions throughout the UK.

Accumulating a collection of real research problems suitable for students of a given higher education level takes time and is difficult without existing academic-industrial partnerships. The IPSHE project aims to solve this problem by sharing such projects between higher education institutions. Real research problems arising from research partnerships could then be used for the benefit of undergraduate teaching more widely than in a single institution. The approach that we identified to enable this was to create a wiki-style contributed website hosted by the University of Bristol and accessible to other UK higher education institutions who can both use and add to it. This would enable us to pool an evolving set of real research problems suitable for students at different levels of HE study. It is hoped that this would lower the bar for other institutions to adopt a similar teaching methodology.

Implementation

A research associate, Dr Oscar Benjamin, was employed to work within the Department of Engineering Mathematics under the supervision of Dr Martin Homer, Professor Jonathan Lawry and Dr Jonathan Rossiter to create and promote the wiki. It was decided to use the University of Bristol's existing, open wiki-hosting service based on Atlassian's confluence 3.5 technology (Atlassian 2012). After creation of the wiki, Dr Benjamin was responsible for contacting the organisers of the relevant teaching units in order to collate the existing projects and upload them to the wiki to form the initial project base. Dr John Melcher was also contracted to provide some part-time assistance in translating, reformatting and annotating the uploaded project resources.

It was decided that each project would need to have a page documenting its use to a potential lecturer/teacher so that they would understand the project without needing to first work through it themselves. In particular it was anticipated that lecturers would want to know quickly whether or not a project was appropriate for their students and how to provide guidance at the initial stages of a project. The resulting format associates with each project the following:

- Summary: a paragraph summarising the project.
- Materials: a brief description of and links to the materials needed by the students for the project.

- Prerequisites: an explanation of the skills and concepts that students would need before attempting the project.
- Hints: guidance for a lecturer in understanding what a good approach for the students might be.
- Extensions: suggestions for how the project could be extended if students are performing well.

The projects have been divided into three categories: *introductory*, *intermediate* and *advanced*, intended to correspond loosely to the first, second and third years of UK mathematics undergraduate study. There are currently around 20 fully documented problems within each level.

It is intended that the wiki will be interactive and that people will be able to leave feedback online and discuss the resources available as well as the addition of new resources. Initially it was thought that the wiki would contain a forum for this purpose. Having more experience with the technology we have decided that it would instead be preferable to use the wiki's comments feature as this enables communication to be contextualised around a specific project (or any other page) within the wiki.

The wiki has been reviewed internally by teaching staff with experience in running undergraduate projects to ensure that the documentation of the projects is valid and helpful to anyone from outside who is hoping to use them. The feedback from this has resulted in changes to specific projects such as adjusting the guidance to pitch it at the right level, based on experience of the abilities of the students at a particular level of study. It is expected that these adjustments will take place continually as experience is gained in applying the different projects with students in different institutions.

The wiki is now at a stage where our primary focus is on its promotion to potential users outside of the University of Bristol.

Evaluation

The key deliverable of this project was a repository of industrial case study problems, available on a public wiki. This has now been achieved. There are currently around 60 problems listed on the site.

We will ask users registering with IPSHE from other higher education institutions to agree to provide feedback on any materials used as part of their curricula. We will also ask for the students involved to complete feedback questionnaires as is already the case internally for our project-based units. This will give us an indication of which materials are most used and are thought to be the most useful, guiding the ongoing development of the resource. As the site begins to be used we will investigate the practicality of accessing user logs to profile and analyse visitors to the site. The ultimate measure of success of the project will be the increase of the use of industrial problems in mathematics programmes throughout higher education. We are still in the process of contacting and waiting to hear back from a number of external users.

Discussion

At this stage in the project, we have successfully created the IPSHE wiki and populated it with an initial body of industrial problems. It is envisaged, however, that the body of problems will be continually changing as some are improved, and as new ones are added. While it will definitely be used within our Department, the primary intention in the creation of the wiki was to involve other higher education institutions both as users and contributors. Whether or not the wiki ultimately achieves this aim will only be known in the long term as it depends principally on the extent of participation in the project by other institutions.

Although there is definitely interest in IPSHE among some higher education practitioners, it remains to be seen how many institutions will adopt IPSHE within their own curricula. IPSHE provides pre-prepared projects based on real industrial and scientific problems. This could significantly reduce the burden of initiating a project-based unit that teaches industrial problems for other institutions. However one hurdle that some institutions may face if they have not had similar teaching programmes before is in having teaching staff that are able to supervise students in the completion of the problems.

The primary task that remains for the project is to promote the use of the wiki as well as the teaching methodology that goes with it. This is key to the project's success both as a positive influence on higher education mathematics programmes and as a lasting resource for teaching.

Further Development and Sustainability

It is intended that the IPSHE wiki be used both as a shared teaching resource and as a motivation for further academic-industrial collaboration in higher education programmes. Now that there is a tangible representation of the project in the form of a website, we will use this to motivate academic and industrial partners to join the project. Interest has already arisen from Dr Mike McCann, a visiting lecturer in our faculty, in using the wiki to host a set of projects designed for an EngD programme, suggesting that the resource could be used for with a wider scope than purely undergraduate study.

The use of the University of Bristol's confluence system ensures that no funding will be required to maintain the hosting of the wiki. It will be used internally for teaching project-based units so it will be regularly maintained by the staff involved with those units. Apart from the burden of administrating access (currently allocated to Dr Martin Homer) a successful wiki will manage itself. So, as long as there is a good system in place for minimising the burden of access management, the wiki is sustainable.

Outputs

The immediate output of the project at this stage is the IPSHE wiki which is available at https://wikis.bris.ac.uk/display/ipshe/Home .

References

Atlassian, 2012. Confluence 3.5. Available via:
http://www.atlassian.com/software/confluence/overview [Last accessed 8 June 2012].

2. Industrial problems in statistics for the HE curriculum

Neville Davies and **John Marriott**, Royal Statistical Society Centre for Statistical Education, Plymouth University

Introduction

A recurring theme throughout evidence-based reports on teaching statistics is that learning statistics is most effective when students work with real data on real problems that they can relate to (see, for example: ASA, 2012; Garfield, 1995; and Garfield and Ben Zvi, 2007). To achieve that for STEM subject students who study statistics, wherever possible they need to get involved in solving real problems generated from within business or industry.

In this project we have developed a freely available web-based resource of real data and problem scenarios that enable students to attempt to solve real, individualised problems that are presented in our industrial partner's business – food production. At the same time, tutor access to the solutions is available. Our use of real data from the food producer provides context to the problem solving activity taking place. The resources created are available for you and your students to use.

Implementation

Generating industrial problems

For the purposes of commercial confidentiality the industrial partner that the Royal Statistical Society Centre for Statistical Education (RSSCSE) worked with for this project is not explicitly named. Every effort is made to prevent identification of any company-specific products.

The visits to the company involved:

- discussion with senior quality managers/personnel;
- tour of production facilities to see 'problems evolving';
- running problem generating workshops which developed problem scenarios with senior managers;
- identification and definition of available data and data to be collected;
- design of data collection processes;
- viewing the production process from the beginning (raw ingredients input) to the end (post baking and packaging).

Our approach was very systematic, involving staff of the industrial partner at all stages of the problem development for the HE curriculum.

Technical development

In parallel to the industrial visits and workshops we:

- developed a randomisation process for problem specific data;
- developed an auto-creation system of problems and solutions with corresponding data sets;
- created a Moodle site to act as a repository for problems and implementation of random selection and download of problems;
- produced a staff area on the Moodle site for tutors to access.

Outputs

The Moodle-based repository of real, industry/business problems from a food producer with associated data sets (which are suitably transformed for confidentiality) provide:

1. a portfolio of different problems from which each student can download individualised random samples from databases of real industrial/business data;
2. solutions to the individualised problems which are emailed to the tutor.

There are three (year) levels containing problem scenarios for statistics topics commonly taught at each level in UK higher education institutions. For the level 1 and 2 problems (outlined in tables 1 and 2, respectively), when students request a problem a zipped folder containing a PDF file describing the problem and a CSV file of real data are downloaded. At each request by a student a problem is randomly selected from a large database of them; each is identified by an individual code printed at the top of each problem page and the solution is emailed to the student's tutor automatically. In addition to being emailed the solutions, tutors can request the solution to any individual problem by logging on to their account and requesting the problem solution by entering the corresponding problem code.

Level 3 contains four detailed problem briefs at final year project level for which students will need to consult with the data provider via the RSSCSE.

The resources are devised and maintained by the RSSCSE, but it will allow colleagues to contribute new problems as and when they are devised or produced.

Problem	Description
A	**Descriptive statistics and graphical presentation** In the first task students are presented with data on the weights of vats containing cooked pie fillings from a food manufacturer. They are asked to use descriptive methods to comment on the production process. For the second task, data on the widths of a cooked product are given for different shifts and students are asked to advise the company on the performance of the different shifts.
B	**Confidence intervals for a single population mean** For the first task students are asked to use descriptive and graphical methods, together with an appropriate confidence interval, to advise a manufacturer on whether the weights of cooked pies meet customer requirements. The second task involves the use of the same techniques as in the first task to compare the weights of a product cooked according to two different recipes.
C	**Hypothesis tests for a single population mean** In addition to the techniques in Problem B the students are expected to construct a hypothesis test for single population means. For the first task students must advise a manufacturer on whether the widths of two different products meet specifications required for a packing process. For the second task the students must discuss whether the weight of meat placed in their meat slice products meets the company's set target.
D	**Confidence intervals and hypothesis tests for two population means** For this problem the students must use statistical techniques for comparing two population means. In the first task students are asked to compare the mean weights of bulk vats containing cooked fillings for two different pastry products. Different sample sizes of weights are made available. The second task requires a discussion of the difference between pairs of end product dimensions.

Table 1: Level 1 problem scenarios.

Problem	Description
A	**One way analysis of variance** In the first scenario students are presented with data on the widths of baked pies that are produced by four different shifts. They are asked to advise the company on whether there is any discernible shift-effect. For the second scenario data on the weights of pasties are given for different shifts and students are asked to advise the company on differences between the shifts.
B	**Two way analysis of variance** For the first scenario students are asked to advise a manufacturer on whether the widths of cooked products are the same on average regardless of product type and shift. The advice is expected to consider the possibility of interaction effects. The second scenario repeats the type of investigation in the first when different recipes are used for a given type of product and four shifts are again involved in the production.
C	**Non parametric one way analysis of variance** The scenarios for this problem are the same as for problem A, the difference being that students are encouraged to use non parametric methods to help solve the problem.
D	**SPC control charts for mean and range** For this problem the students must use mean and range statistical process control charts to explore the performance of a company's production. In the first scenario students are asked to consider whether the lengths of sausage rolls meet requirements and samples are available both for constructing the charts and monitoring subsequent production. The second scenario is similar to the first for a case in which the widths of pasties are to be monitored.
E	**SPC control charts for the mean process capability** For this problem students must advise a company on the performance of a process by considering process capability. The two scenarios involve the lengths of chicken pies and the weights of meat and vegetable pasties.

Table 2: Level 2 problem scenarios.

Evaluation

As each step in creating industrial problems for the HE curriculum depends on previous steps, we adopted a strategy to continuously evaluate the staged development of the use of the real data, the problems created and latterly the web-based delivery mechanism of the resource.

Evaluation by the providers of the data and associated problems was carried out by running a formal evaluation workshop with four members of staff from the company. We discussed a number of the problem scenarios, as a result of which the content and context of some were changed.

For evaluation by teachers of statistics in HE, at the end of the project 16+ colleagues from within and outside the UK were invited to try out the resources by downloading the problems and solutions and commenting in broad terms on their usefulness for teaching and learning. The feedback is generally very encouraging. Some selected comments:

- "The clear explanation of the context to the problems is very effective in making the data analysis inviting";
- "The data you have is useful, clear, easy to understand and easy to access";

- "Basically, it is easy to set homework for a class and I think it is further a great idea that solutions get mailed to the tutor, so well done, I LOVE it!";
- "I have had a brief look at your website and I think that the database and problems are excellent and would be very useful for lecture support material";
- "The questions are clearly put and test some basic skills. They did seem somewhat 'samey' but that's not necessarily a bad thing";
- "I think it's a good idea and should prove useful. As you will see, my criticisms have to do with the plausibility of the story line in the Level 1 example";
- "Generally speaking, I thought that these were interesting and well explained/set out. I am sure that they will make a good resource for students to use when learning on their own".

There were no fundamental issues identified but there were some typographical errors detected.

Discussion and next steps

Our approach worked very well with positive feedback from the industrial partner. The target audience for the industrial problems are students and tutors on STEM courses that teach statistics with the impact expected to be long-term. In order to properly evaluate the long-term outcomes of this project the portfolio of problems need to be used by students on courses at the three different levels catered for and, in conjunction with course tutors, piloted and evaluated over at least two years, which was not possible within this funding.

We would advise others who wish to mimic what we have done to hold regular workshops for problem generation without which this project could not have been delivered effectively. If it were possible, we would wish to expand the portfolio of industrial problems to draw data and problem scenarios from a wider range of industrial/business partners.

The RSSCSE is committed to running the project in as many UK universities as possible in 2012/2013, as funding allows, to better evaluate its implementation. At the very minimum all materials developed by the project will be maintained on the RSSCSE web site www.rsscse-edu.org.uk. A password is required. To obtain this please email admin@rsscse.org.uk.

A longer version of this report, containing more detailed descriptions of the created resources and technical information on the development, is available via www.rsscse.org.uk/activities/he-activities/hestem.

References

American Statistical Association (ASA) (2012). *Guidelines for Assessment and Instruction in Statistics Education Reports*. Available via http://www.amstat.org/education/gaise/ [Accessed 7 June 2012].

Garfield, J. (1995). How students learn statistics. *International Statistical Review*, 63, 25-34.

Garfield, J. and Ben-Zvi, D (2007). How Students Learn Statistics Revisited: A Current Review of Research on Teaching and Learning Statistics. *International Statistical Review*, 75, 3, 372 – 396.

3. A Statistical Awareness Curriculum for STEM Employees

Neville Davies and **John Marriott**, Royal Statistical Society Centre for Statistical Education, Plymouth University

Introduction

In this project we created a learning environment that raises statistical awareness among STEM employers and employees and:

A. shows the need for employers to audit employees' statistical skills and act on the evidence provided by the audit;

B. builds an understanding of the role of statistical skills in developing a fully competent workforce;

C. develops an appreciation of how statistical skills can be improved.

We created a web-based tool for employers to audit their employees' statistical skills. We investigated and identified:

i. a statistical curriculum that STEM graduates should be able to understand and do;

ii. statistical issues that STEM graduates should be able to discuss on the basis of what they know, but not necessarily be able to do;

iii. the statistics-related areas that STEM graduates should be able to critically evaluate.

We also identified a useful statistical topic applicable to a range of STEM contexts, which can be taught to STEM employees using distance learning web resources. We give an example for teaching this topic to STEM employees through a problem solving approach.

Research

In June 2011 the Advisory Committee on Mathematics Education (ACME) published the report 'Mathematical Needs: Mathematics in the workplace and Higher Education' (ACME, 2011). As part of their research ACME interviewed "employers and employees from about 25 companies" to investigate staff involvement with mathematics in the workplace. As a result of these interviews a number of case studies on the use of mathematics in the workplace were developed. The majority of the case studies developed involved obtaining relevant data, graphical representation of results and some statistical analysis/processing of the data. In addition for six of the eight industrial sectors they considered, verbal evidence is presented from managers that statistics at varying levels of complexity is required knowledge for some members of the workforce.

The Sector Skills Council for Science, Engineering and Manufacturing Technologies (Semta) is currently undertaking work to inform Further Education and Higher Education institutions and other 'supply-side' training providers of the detailed skills and knowledge required for technician and engineering posts within their sector. We are grateful to Semta for supplying details of this current project and access to job profiles and tables of specific Mathematics skills 'enabling, applied, doing technical and practical activity to get job done' for each of the following job descriptions:

- Technician (Design & Manufacturing);
- Engineer (Systems Designer);
- Senior Engineer (Product Owner and Support);

- Principal Engineer (Manufacturing Engineering Manager);
- Chief Engineer -Electrical Systems.

An examination of this information reveals that a Senior Engineer (Product Owner and Support) is expected to have adequate knowledge of and make frequent use of Statistical Methods together with adequate practical experience in applying their knowledge, however they might be expected to require some guidance, advice and/or supervision when using Statistical Methods. Engineers in the remaining four posts are expected to make frequent use at least two of: Statistical Methods; Statistical Techniques; Applications of Statistics; and Probability. In addition they are expected to have expert knowledge of these topics with a comprehensive level of practical experience and achievements in the subject.

While the information provided has proved extremely informative, the way in which the skills have been classified does not provide the topic-by-topic guide to specific statistical skills that are explored in detail by this project.

Project Activities

We consulted STEM employers and employer groups about their statistical needs. We designed a feedback form for employers and employees and wrote an online competency survey. Employers, employers' groups and others visited or consulted were: British Telecom; the Met Office; Toyota Manufacturing; Rittal-UK; Plymouth Manufacturing Group (PMG); the sector skills council for Science, Engineering and Manufacturing Technologies (Semta); the Confederation of British Industry. In view of the perceived lack of statistical skills, the employers all made use of additional training in some skills present in the curriculum that STEM graduates should be able to fully understand and use.

A telephone survey of STEM professional bodies was undertaken and their views on a statistical curriculum necessary for professional status were solicited by investigating whether they had any published statistical curriculum requirements. The following professional bodies were contacted: Biochemical Society; Institution of Agricultural Engineers; Institution of Civil Engineers; Institution of Engineering Designers; Institute of Marine Engineering; and The Engineering Council. It became apparent from the institutions surveyed that there is no agreed statistics curriculum across the professional bodies. Several of them refer to the Engineering Council Standards (2011a, 2011b). These are interesting in that their Standard for Engineering Competence states general requirements for the ability to conduct statistically sound investigations but holds back from specific curriculum content, except perhaps in expecting engineers to "engage in … continuous improvement systems". The council also publish a standard for the Accreditation of Higher Education Programmes. These standards (there are different requirements for the different degrees) do not mention specific content for any statistics curriculum, instead the requirements are for mathematical, quantitative or computer tools and methods needed for the solution of engineering problems.

We also surveyed a range of universities to explore the undergraduate statistics curriculum in STEM subjects. We reviewed the online syllabus content for statistics modules on STEM science degrees at a sample of universities to investigate the extent to which statistics may be taught as part of a first degree in the subject. The following universities that offer study in at least one of biology, chemistry and physics were contacted: Plymouth; Imperial College; Bath; Birmingham; Manchester; Newcastle; Durham; Glasgow; Cardiff and Bristol. The results indicate that, as with the engineering professions, there is no clear consensus even within individual disciplines. In biology the requirements for the institutions sampled range from an optional study of statistics, through basic statistics and core skills to experimental design. The requirements in Chemistry for the sampled institutions, where they could be identified, appear to be low level basic statistics with one notable exception of Statistical mechanics. This same pattern of subject requirements also appeared among the physics courses.

Audit questionnaire and curriculum

The first draft of the audit and proposed curriculum were compiled following review and feedback from professional bodies, meetings with employers and employer focussed organisations and was also informed by a review of the statistics taught curriculum in STEM HE subjects and cross comparison with the ACME report. The initial proposal for the audit and curriculum was seen by the getstats campaign board, the SW region of Semta, the Confederation of British Industry (CBI) and Shirley Coleman, Technical Director & Principal Research Associate of the Industrial Statistics Research Unit (ISRU) at Newcastle University.

Informed by the first stage of the evaluation process, we developed a pilot version of the audit questionnaire for detailed discussion with all four employers, which led to considerable changes in content and style of the questionnaire and also to some additions to the statistical topics that STEM graduates should fully understand and do. There was a consensus that the curriculum defining those statistical topics that in an ideal world STEM graduates should know about before graduation and subsequent employment should be the same as the curriculum for the audit. However the employers differed as to the importance of the skills graduates should be able to identify and critically evaluate or the skills graduates should know about. The most positive response was that these provided a useful and desirable additional skill set, and none of the suggested skills were seen as being completely unnecessary.

The feedback from the second stage of the evaluation was incorporated in an online implementation of the audit questionnaire, and employers were invited to ask employees to take part in a trial and to feed back comments on the ease of use and suitability of the 'finished product'. Two employers asked small groups of newly employed staff to do this and the feedback had formed the final online version of the audit.

Three of the four employers consulted expressed an interest in making use of the online audit questionnaire, however none of their individual timetables for implementing skills audits as a prelude to selection and allocation of employees to continuing professional development in statistics allowed for this to happen during the course of this project. We would highlight the importance of recognising that the working constraints faced by industrial partners are different from those in academia. This makes it important to design time frames for projects that make them more likely to match industrial partner time restrictions.

The electronic version of the questionnaire can be used by any employee as a self-audit tool: employers were very firm in the conviction that the tool should be used as a way to inform an individual about his or her CPD needs. Discussion with their line managers should be done with a hard copy version of the responses.

During the early stages of the project we devised what we believed would be a useful curriculum for STEM employees. Following discussions with employers, these topics were reformulated in terms of learning objectives and the order in which the three curricula were presented was changed to reflect perceived employer priorities. In the light of discussions with STEM employers the topics were modified and supplemented with additional topics. The modified curricula are contained in the appendix to this report.

Teaching Example

We designed an exemplar curriculum teaching resource in Analysis of Variance. In designing the resource we adopted the following guiding principles:

- it should deal with a topic that employers would perceive as forming part of the curriculum dealing with statistical topics that STEM graduates should be able to identify and critically evaluate;
- it should be a topic that is applicable (albeit with differing context) across STEM disciplines;

- it should consist of a PowerPoint presentation, notes in support of the PowerPoint and an additional exercise with supporting data;
- it should allow for both low and intermediate levels of mathematical skill.

Resources

The audit tool, curricula and exemplar materials are available via the Royal Statistical Society Centre for Statistical Education (RSSCSE) web site www.rsscse-edu.org.uk by following the link to 'A Statistical Awareness Curriculum for STEM Graduate Employees'. We will make all future resources developed as an extension to this project freely available on the RSSCSE web site also. A password is required. To obtain this please email admin@rsscse.org.uk.

A longer version of this report, containing job profiles provided by The Sector Skills Council for Science, Engineering and Manufacturing Technologies (Semta), notes of site visits to STEM employers and details of the audit questionnaire, is available at www.rsscse.org.uk/activities/he-activities/hestem

References

Advisory Committee on Mathematics Education (2011). *Mathematical Needs: Mathematics in the workplace and Higher Education*. Available via: http://www.acme-uk.org/media/7624/acme_theme_a_final%20(2).pdf [Accessed 8 June 2012].

Engineering Council (2011a). *The UK Standard for Professional Engineering Competence*. Engineering Council, High Holborn, London WC1V 7EX.

Engineering Council (2011b). *The Accreditation of Higher Education Programmes*. Engineering Council, High Holborn, London WC1V 7EX.

Acknowledgements

The current economic climate has made it more difficult than ever to enlist employers in projects of this nature. The project team are extremely grateful to all the individuals and organisations who have helped us contact employers and to the employers, and their employees, who have made this project possible.

Appendix: Agreed Statistical Awareness Curricula for STEM Employees

This appendix contains the three curricula that were agreed after discussions with a range of STEM employers. The specifications cover what STEM graduate employees should:

1. fully understand or be able to do;
2. be able to identify and critically evaluate;
3. know about.

1) Capabilities: STEM graduate employees should

- be able to use a problem solving approach to make evidence based decisions, namely
  - identify relevant questions that need to be answered; identify the target population; recognise the population structure and properties; choose an appropriate sampling approach that could be used.
  - decide what needs to be measured/recorded; identify the corresponding measurement scale(s); know how to collect or arrange collection of the required data.
  - identify appropriate summary measures that could be used; identify appropriate graphical presentations that could be used; process the data obtained in the manner identified.
  - assess the initial questions raised in the light of the results obtained; recognise whether more questions need to be addressed; decide on actions as a result of the findings
- have an awareness of data quality, how data are generated and where it comes from;
- use probability as a measure of uncertainty; calculate probabilities for compound events; understand and calculate conditional probabilities (for example using a bivariate table);
- understand how common causes (inherent or natural variation) and special causes (external source of variation) can have an impact on processes in STEM industries; understand variability and propose appropriate summary measures and graphical representations to aid understanding of its impact in different problem situations;
- understand the importance of and be able to effectively use graphical presentation of data;
- know how mean range and standard deviation can be used describe distributions and know how to distinguish between discrete and continuous distributions;
- understand the process by which inference is used to make decisions; make appropriate inferences in different problem situations;
- know the central limit theorem and understand its importance to inference;
- know how to use basic statistical tests and interval estimates and understand the situations in which they are appropriate;
- understand how bias can arise in sampling and measuring in STEM industries; undertake appropriate actions to reduce bias when it arises;
- understand what missing values are, how they can arise and what action to take when they do;
- understand how correlation can be used to measure association between two variables;
- use simple linear regression;
- understand how some variables can change through time and that running means can be used to estimate trends;
- know how control charts can be used to monitor processes and how measures of process capability can help inform decision making in STEM industries;
- know how to interpret trends and runs in control charts.

2) Analysis: STEM graduate employees should be able to identify and critically evaluate

For a given presentation/report/study/publication, STEM graduates should be able to:

- identify and critically evaluate the nature of sampling methods used;
- identify and critically evaluate the experimental design employed;
- assess the quality of the questions where a questionnaire is employed and critically evaluate the use of the questionnaire in the context;
- understand written descriptions associated with numerical and/or graphical presentations and critically assess their quality and relevance;
- identify important points that can be made from the information provided and critically assess points made in the presentation for accuracy and relevance;
- identify any omissions from the work in the light of its aims and identify any incorrect use of statistics;
- offer constructive criticism of the conclusions drawn by the author/reporter.

3) Knowledge: STEM graduate employees should

- know about applications of probability and risk and be aware of the distinction between relative and absolute risk;
- know that samples that are to be used to make wider inferences should be drawn using well designed experiments or sampling frames;
- know what types of information and data are collected by government and other national and international agencies and be aware of the use to which such data should be and is currently put;
- be aware of how statistics is used in industry and commerce.
- be aware of areas in which statisticians are currently employed and know about the types of problems they are addressing;
- be aware of the use of statistical indicators in measuring performance and know about the strengths and weaknesses of such indices;
- know that very large data sets are increasingly used by industry, commerce and government and be aware that they pose special problems of analysis and know how they are used;
- know about the use of statistics in different applied areas for example in recording, investigating and reporting crime and its use in medicine in developing new medicines, recording and reporting the quality of patients' experiences;
- be aware of the basic technical terms that might be encountered in everyday life such as 'significant', 'confidence interval', correlation and standard deviation'.

4. Assessing student teams developing mathematical models applied to business and industrial mathematics

Edmund Chadwick, **Kevin Sandiford** and **David Percy**, School of Computing, Science and Engineering, University of Salford

This article first appeared in MSOR Connections 11(3), pp. 22-24.

Using case studies and group work, this project attempted to provide students with experience of business and industrial working practices and also to address the issue of how to solve practical mathematical problems. Students were organised into teams and tasked with solving a problem presented in the form of a real world industrial case study. Each group was assessed on their problem solving abilities, mathematical modelling skills and also on their team work and contribution to the group. Industrial partners were also invited to judge the final solutions presented by the group and feedback was offered, based on the 'real world' situation presented by the case studies.

Background and Rationale:

The methodology used to tackle the issue of problem solving was not a traditional academic route by examination or essay, but instead a pro-active approach through a team-based problem-solving format familiar to the world of business and industry. The idea for this approach was to prepare the students for the world of work and to highlight the way in which they will be expected to use their mathematical knowledge in their future careers. A vital part of this was exposure, understanding and experience of the development of mathematical models from concept to testing.

Throughout the module, seminars from guest speakers on a spectrum of mathematical applications used in industry would expand the 'real world/industrial' context to give students insight into the world of work and the way mathematics may be used in their jobs. The module task would assess the students' ability to do this. Industrial partners identified team working and problem solving as areas of vital importance so this project attempted to incorporate both into a series of tasks.

Students would be exposed to the various roles played within a team and so have the opportunity to assess their preferences, performance and capacity for changing role particularly in the context of developing mathematical models. This would provide valuable information to the student in understanding their strengths and weaknesses within group dynamics while also providing opportunity for reflection and change.

By the end of the module, the students would have had real experience of the type of roles played within teams, and be able to reflect upon how this dynamic directed the outcome of the task solution as well as how they responded to it. They would have been tested and assessed for a variety of business-like attributes not assessed by a standard academic module. This would help us produce more business-aware and business-ready graduates for the workplace.

Implementation:

The industrial speakers represented a range of different sections and included: DSTL, CMS intelligent banking, Manchester Medical Academic Health Sciences (NHS), IBM, an expert court case witness, IMA, and the Sellafield OR group. The industrial list was compiled from existing staff contacts and graduate alumni from the university. As well as describing what they do, which was almost exclusively mathematical modelling, the guest speakers also described the group structure of their companies, essentially project leaders managing small teams.

These talks were intended to provide an insight into working practices and demonstrate how the course structure and content reflects the industrial world. Topics covered by the talks included the career path, company profile and use of mathematics by the company. The work practices covered problem solving, communication and team-working thus providing the context, understanding and direct connection from the module to the world of work.

Two open-ended case studies were presented consecutively to student teams. The case study titles were:

1. What are the hours of daylight and darkness?

2. What is a variable APR mortgage?

The titles chosen were deliberately open-ended, and the mathematics required trigonometry and series respectively, typically to A-Level standard, so as to free the groups to follow their own direction for solution.

Students were arranged into teams of four members. Each member was given a specific role, and the team members and roles changed upon completion of each case study. The groups were left to organise themselves, arrange meetings and liaise with an academic adviser.

The four roles in each group were chair, secretary, task coordinator and technical coordinator. The groups worked on developing a mathematical model to answer the case study questions from concept, design and solution, through to testing. Groups were required to produce a minutes book, project plan, specification and final report which detailed their mathematical model. They were also required to give a group PowerPoint presentation for an audience of industrialists and academic staff, to which each team member contributed. Following these presentations the audience offered immediate feedback.

The academic adviser played a supportive role and was required only to respond to questions from the group. The academic adviser observed and noted the interaction between members of the groups, and how they adapted to being given roles and the change in roles between case studies. Both adviser and students were required to share reflective comments on this experience as part of a wider personal development process for the students.

As well as the academic advisers, the module coordinator had responsible for contacting, inviting and arranging the visits of guest speakers from business and industry, facilitating the meetings scheduled between the academic adviser and the student groups, making the students aware of the format of the deliverables with deadlines via the handbooks and the case studies, as well as organising the schedule for the student group presentations attended by the group of industrialists.

Evaluation

Evaluation took the form of feedback from the students and industrialists. Feedback from the students was required in the final report, in the presentation, and also in a separate reflection sheet. Feedback from the industrialists was given verbally.

From the students' final reports, there was significant positive feedback. They were asked to give an evaluation of the success of their project, identify what worked and went well and what did not work. The evaluation of the project covered the group dynamics as well as the deliverable outputs. The general response to this section was that they saw this project as an opportunity to problem-solve and provide their own solution, which was a "refreshing change" from the format in other modules.

However some negative feedback was present around group dynamics, in particular about group members that didn't contribute significantly and didn't come to pre-arranged meetings. One suggestion to resolve this might be to attempt to evenly distribute the students so each group had a balanced cross-section of ability and motivation, as the main problems came when two or more poorly motivated students resided in the same group.

In terms of the presentations, the students were very critical of themselves focusing in on what went wrong. They did not give balanced critiques which also highlighted the positives.

In the reflection sheets, students were asked to highlight key decisions that most influenced the direction of the assignment, which roles they preferred and how their involvement changed with the change in role. Although no common themes came out of these sheets as they reflected the personal involvement of each student; in writing down and having to reflect in this way, it is clear from the majority that the students were starting to reflect on their personal preferences within a group. It was also clear that their interaction changed with changing role, and each role was beneficial in developing them in different ways. It could be interesting in the future to see if more could be made of this, in terms of feeding into the student understanding their personal preferences, feeding into a personal development plan.

Feedback from the industrialists was given verbally and expressed the view that this type of project was immensely valuable in exposing the students to the type of work and working environment that would be expected of them in their future jobs. They said the case studies posed were challenging and that they were surprised by the high academic level achieved by the groups in the reports and presentations, and the variation in the directions taken by each group.

This work was presented at the Embedding Graduate Skills workshop in November 2010 at Sheffield Hallam University and at the CETL-MSOR Conference 2011. It was written up for the Developing Graduate Skills booklet [1].

Discussion

The principal goal, of exposing students to a problem-solving way of working akin to the work environment developing mathematical models, was successful. The realistic structure of the project task and the industry involvement through the seminar series and assessment made the task and the mathematics relevant to the students enabling them to see how their course is used in industry. This is one key reason why the approach was successful and appeared to make the module less ‘academic’ in the eyes of the students.

Another important success was in getting the students to think about how they worked in the reflection sheets and to start reflecting on their actions. This was successful in terms of the student response, in that they found it beneficial to themselves, although it was not directly assessed. As mentioned above, this type of activity could be used to feed into a personal development plan to identify the strengths and weaknesses of individuals in order for them to focus on such areas for growth.

A key lesson that was learned was that industrial involvement was paramount for success. Although not essential to the running of the module, the students responded to and respected the input and advice given by the company representatives over that given by the academics or careers staff. The company involvement made the content of the module real and relevant.

Also, the difficulty in obtaining a meaningful evaluation was highlighted. Feedback in the presentations and reports from the students focussed on the negatives of group members and of their own input. The students seemed unable to make a rounded assessment and present the positive aspects of their work.

Further development and sustainability

Future development will consider more carefully how to evaluate and adapt the wording used on feedback and reflection sheets to try to draw out more of the personal development that is taking place. It will be emphasised that a rounded critique rather than a negative criticism is required. More emphasis in the final report could be placed on the students’ assessment of their personal and group development, perhaps with an additional section required on this.

An online peer assessment system such as WebPA [2] could be introduced as a possible alternative to assessing the group work element.

The students' overwhelming recommendation is for the module to be run again, and the university is committed to sustaining this as an essential embedded module within the degree programme for the foreseeable future.

References

1. Chadwick, E. (2011). Student Teams Developing Mathematical Models Applied to Business and Industrial Mathematics. *In*: J. Waldock (ed) *Developing Graduate Skills in HE Mathematics Programmes: case studies of successful practice*, pp. 36-38.
2. *WebPA* http://webpaproject.lboro.ac.uk/ [last accessed 10/10/2011].

5. How realistic is work-related learning, and how realistic should it be?

Edmund Chadwick, University of Salford

Jeff Waldock, Sheffield Hallam University

Noel-Ann Bradshaw, University of Greenwich

Louise Orpin, Operational Research Society

David McNulty, University of Salford

Makhan Singh, Institute of Mathematics and its Applications

Terrance Haydock, University of Central Lancashire

Charlie Ellis, North West Universities Association

Peter Rowlett, Maths, Stats and OR Network

Nigel Steele, Institute of Mathematics and its Applications

Overview

The following report emerged from a half-day workshop with the above title at the University of Salford, on 7th March 2012, attended by the above authors with the following abstract to lead discussion:

> *"Work-related learning at university often involves using subject matter that is only loosely related to the world of work. Realistic problems quickly require specialism, and consequently it is difficult to find realistic subject matter pitched at an appropriate technical level for the student. In work-related modules, academia often simulates simple (unrealistic) versions of industrial problems. However, there is more to work-related learning than simply attempting an accurate simulation of work-related problems. For example, in engaging the student in a teaching situation the process to achieve a solution in work-related learning is often valued, and similar to that used in the workplace. For example, similarities are often team-based work and the development of mathematical models. Also, exposure to work-related issues in general is invariably seen as of benefit, such as input from employees through presentations about their companies, feedback to students and delivery of curriculum material."*

What follows is a compilation of the subsequent discussions between the authors.

Introduction

The current economic climate requires that those seeking employment in a professional capacity be of the very best calibre, and while the mission statement of universities is aimed at producing such talent, there are ways and means to further enhance a student's profile. An employer, on interviewing a potential employee with a better than average degree, will more than likely surmise that he/she will be skilled in problem solving, brainstorming and various other attributes of this nature. The employer will not however, know if he/she has the abilities to carry this knowledge over to industry and use it to tackle not just theoretical problems but also practical problems in a practical environment.

In this paper we discuss work-related learning. Work-related learning, which simulates work-related activities within a university setting, is distinct from work-based learning, where learning takes place at a workplace while the student is engaged in activities as though they were an employee. The main purpose of work-related learning is preparation for employment, and consequently the requirements of the workplace are paramount in answering the question.

Companies employing maths graduates generally agree that the “soft” skills of communication, team-working and problem solving are important in a maths graduate employee. In providing these work-related skills at university, there is no necessity for realism, as they can be developed free from the context of the world of work. Most maths degrees offer exposure to these “soft” skills, but many do not provide a particularly realistic framework in delivery. However, companies will also prefer and be impressed by graduates who at interview display a more developed level of exposure to work-related learning, and this often requires a greater degree of realism. Also, companies seek professionally aware employees, and this is important to the professional bodies and the individual’s own personal professional development as well. In the case of developing professionalism, realism is essential. Successful interventions by Higher Education Institutions (HEIs) that enable this realism require employer engagement in all of its forms.

These issues are discussed in greater depth next. We provide a curricula and professional context for the need to develop work-related learning and outline key areas where this might take place: problem solving projects and team-work. Finally, we discuss raising awareness in students of the range of career options and employment sectors open to them and the role employers might play in assisting with work-related learning.

Curriculum context

With the exception of mature students it can be assumed that the vast majority of new students have little or no experience in the working environment. Work placements are offered at many universities but not taken up by all students. Work-related learning may, if applied effectively, provide graduating mathematicians with improved skills and performances in interviews and CV building, giving them the advantage over their peers. An understanding and awareness of professional development may also be an advantage for an undergraduate in terms of both motivation and determination of their career path.

Work-related learning within the HE curriculum includes both the development of key skills that are required in the workplace and engagement with realistic work-related scenarios. The former can take place across the broad curriculum while the latter – particularly in a mathematics degree – is likely to involve the application of these skills, along with core mathematical skills, in extended problem-solving exercises such as case studies.

If those designing the HE mathematics curriculum expect graduates to possess the employability skills such as communication, team-working and self-reliance that employers want, then activities that form the curriculum should in turn be designed to foster them [1]. Ideally, this should take place at all levels developmentally and be assessed – a process that is more easily implemented with institutional support. This will help students to recognise the importance of such skill development, be aware of how and where the development takes place and be able to articulate this when required. It will be seen from this discussion that for work-related learning to be effective, it needs to be integrated into the HE curriculum in a coherent, planned way and reinforced in many (if not all) modules.

However, difficulties can arise in getting students on board with unfamiliar teaching methods. Examples such as preparation for interview technique in the form of public presentations can leave some students puzzled as to the application. A lack of motivation can sometimes be due to students not necessarily understanding the use or importance of this learning and how it can be transferred to the work place.

Professional context

Professional bodies look to foster continuous professional development for their members, and also look to award professional titles to their members according to achievement in various professional competencies and employability skills. The Operational Research (OR) Society encourages its members to continue their professional development through accreditation which enables members to certify their achievements in their job. The Chartered Mathematician

(CMath) designation represents high levels of professionalism and competence in mathematics and is awarded by the Institute of Mathematics and its Applications (IMA). To achieve both awards candidates must demonstrate career specific abilities as well as the following: problem-solving; application of techniques; communication and literacy; project management; team working; leadership and management; business and customer awareness; application of information technology; commitment to professional development.

Problem solving project activities

For problem solving exercises to be suitably related to work, they should be drawn from real problems that have occurred in the workplace, and close links with relevant employers should be exploited when collecting examples of such exercises. Added realism comes from requiring students not just to solve the mathematical problem but to also formulate the problem mathematically at the outset (with appropriate constraints and caveats) and to communicate the results in an appropriate form for different audiences. This may involve summarising the results in the form of a poster, a presentation or an executive summary, where they are required to identify what results are needed, and to qualify them in an appropriate way taking account of the constraints. The key employability skills noted above will be used throughout the process, and students will gain effective work-related learning by putting them into practice.

Practical projects implemented by staff have proved effective at Salford in giving students a taste of team-work as well as benefiting from attempting to solve open ended problems [2]. For most, these have led to developments in their mathematical reasoning and an understanding of the nature of an ‘unsolvable problem’. Realising that the method is sometimes more important than the solution can be a real revelation to a young mathematician, something that many believe is crucial in developing a well-rounded mathematical, logical approach and has clear applications to the working world.

At Salford, difficulties were found with finding real world problems for the students to tackle. Although the problems tackled were ‘open ended’ and had a real-world context, they had to use mathematical techniques that were within the existing skills set of the undergraduates, and this restricted their realism. However, greater realism leads to a requirement for more specialised maths knowledge, and likely to be specific to a particular employment sector, which may alienate students not interested in this area, and also likely to require a greater amount of time available than is feasible in order to cover it in sufficient depth.

Team-work

Employers have expressed reservations as to how university group work can mirror what is required from work-based team work.

As part of an HE STEM project entitled ‘Making Maths Graduates More Employable: an enhanced role for tutors’ the maths department at the University of Greenwich hosted a team-building exercise run by the Adab Trust (an organisation dedicated to achieving graduate level employment outcomes for students from Black, Asian and Minority Ethnic communities) [3].

Dermot O’Brien from the Adab Trust feels that employers look for evidence that graduates can work in a team rather than the fact that they have participated in a university-style group project. In the workplace teams are often drawn from different departments with members not necessarily knowing each other beforehand. Often there is a hierarchy, so some team members can be more senior than others. University group work rarely provides this experience; one would have to create an opportunity for collaborative projects with other departments / faculties including students from different year groups. Such projects do exist but are few and far between as they are obviously difficult to administer and evaluate.

Dermot also made the point that it would be beneficial to encourage students to take part in outside activities that show an ability to work as a team. These include playing a musical instrument in an orchestra or band or playing a team sport. Students often do not realise the value of such activities in the context of their CV.

The Adab Trust team-building exercise at Greenwich was attended by nine teaching staff and eight 2nd year maths students. The staff and students were assigned to mixed teams and then took part in several team building exercises. One of these exercises involved having to transport a table tennis ball from one end of the room to another without touching it or allowing it to make contact with the floor. Each team member was given a piece of guttering in order to transport the ball. At the end of the room the team had to deliver the ball into a small cup.

Activities like these enabled students and lecturers to work side by side. In each group one of the students was given the job of team leader and had to be prepared to give instructions to their lecturers as well as to their peers. Some students found this situation challenging. After one run-through of the activity a team member was blindfolded and so the team now had to work together even more coherently in order to enable this person to take part successfully. All the students who attended said that this was a very worthwhile workshop that they felt would have benefit for them in terms of demonstrating team-work skills in competency based interviews. A typical student response from the feedback is given next:

> *'Thank you for the privilege to work with you today and all the teaching staff. Personally I feel that if you could arrange such events very often it would help to prepare us for the future challenges of employment.'*

Afterwards staff discussed the possibilities of including activities like these within the curriculum and there was some talk of incorporating them into Maths Arcade sessions, which are social sessions particularly for the students centred around playing various games, particularly board games requiring strategic thinking, and puzzles. It was noted that it would be possible to create similar team building exercises incorporating a mathematical puzzle solving element; a suggestion for a future project maybe?

Careers awareness

By providing workshops, tutorials and interactive learning material, the student can become well equipped with not just theoretical knowledge, but the practical case studies that bring that theory to life in everyday business. Mathematics can be seen in every major industry and by highlighting these industries with relevant case studies, and how they incorporate mathematics to become successful, the market place for people equipped with relevant degrees becomes wider.

Involvement of employers

Companies can play a crucial role here helping to bring context to learning for students; knowing the application of mathematical study can only increase student motivation/learning. An understanding and awareness of professional development can be achieved in part by activities such as visits to and from associated companies and professional bodies, an example being the talks given by outside speakers from various professions involving a mathematical background provided by the Mathematics department at Salford University. This kind of exposure to the type of jobs available certainly prompts students to consider their future options and puts part of their impending qualification in some perspective.

Another way of involving companies is through them giving careers advice to students. Often mathematical sciences undergraduates lack careers awareness to what paths their mathematical science degree may lead them. A suggestion is for company HR departments to provide mock interviews at the site, having undergraduate students arrive at the company and be interviewed (with feedback). This would be great in providing mathematical science students a 'real life' interview process. However, this suggestion is constrained by the requirements in time and effort to set up of both the HEI and the company.

Discussion

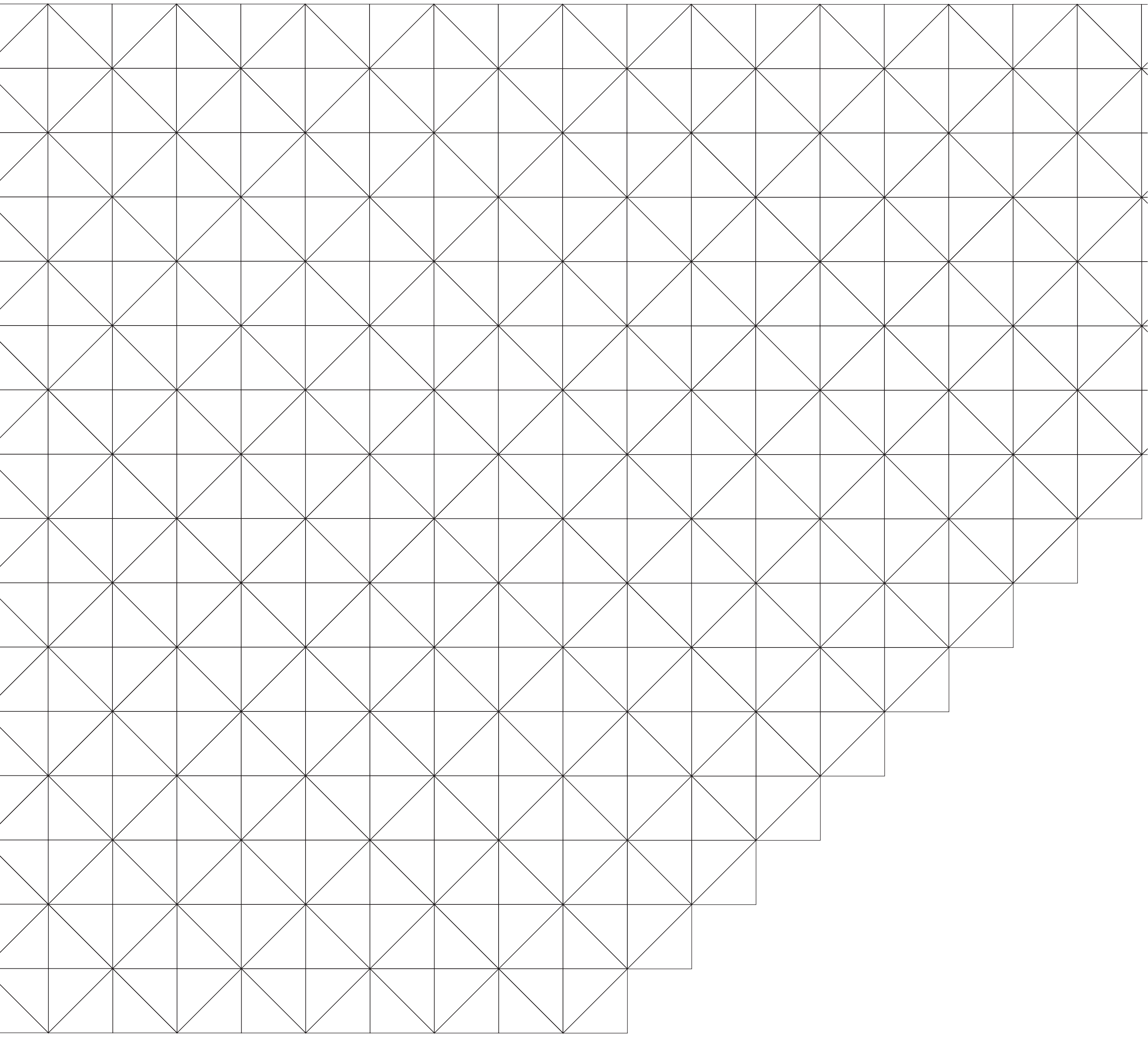
It is clear that the "soft" generic and essential skills for mathematics graduates required by companies such as communication, team-working and problem-solving do not necessarily require to be developed within a realistic work-based context. However, emerging from the workshop discussion and subsequent author contributions, more developed work-related skills that are desirable in a mathematics graduate do require an authentic connection to the workplace, and this is a message coming through clearly from the preceding discussion areas.

An HEI can provide base-line work-related skills that don't require realism, but to develop these further requires realism in work-related learning throughout the degree programme in all modes of study, and also in all aspects of the university experience. However, there are difficulties highlighted in achieving realism which have been noted in problem-solving modules, in team-work activities and in employer engagement. There are constraints which mean that there is a trade-off between the extent of realism and also with what is practically possible. For example, in the problem-solving modules discussed earlier, the greater the realism in the problem the greater the specialism in terms of mathematics and employment sector, but this is constrained by the student knowledge-base and also the time allocated to complete the project. Similarly, the team-work desired by companies, which involve teams comprising different skills sets and different experience levels, are again constrained by what is feasible to set up and manage by the academic staff. Also, there are constraints to the extent that realism in employer engagement activities can be achieved because of the considerable input required by both company and HEI in setting up realistic scenarios.

However, despite these constraints, the discussions also indicate how realism can be instigated, and it is clear that authenticity is provided principally by employer engagement in all its forms, extending even beyond the narrow confines of the degree programme itself. The positive feedback from students for many of these activities is the best indicator that striving for realism, although difficult to achieve, is a worthwhile endeavour.

References

1. Pegg, A., Waldock, J., Hendy-Isaac, S., and Lawton, R. (2012). *Pedagogy for Employability*. HEA.
2. Chadwick, E., Sandiford, K., and Percy, D. (2011). Assessing student teams developing mathematical models applied to business and industrial mathematics. *MSOR Connections*, 11(3), p. 22-24. [Reproduced in this booklet on page 41-44.]
3. Bradshaw, N., Mann, T., Parrott, A.K. and Ramesh, N.I. (2012). *Making Maths Graduates More Employable: an enhanced role for tutors*, Report for HE STEM to be published via www.hestem.ac.uk.



6. Models of Industrial Placements for Mathematics Undergraduates

Tony Mann, University of Greenwich

Introduction

For many years, ‘sandwich’ industrial placements have been part of some UK mathematics degrees, and such placements are widely regarded as highly beneficial for students. As Universities increasingly aim to improve the employability of their graduates, other forms of industrial placement have been introduced. This short report aims to give an overview of some of the different models of industrial placement for mathematics undergraduates that are currently in place, discussing some of the advantages and disadvantages of different models.

Industrial placements

It is not the purpose of this report to discuss in detail the value of industrial placements for undergraduates, which are widely accepted. They are well summarised in a Royal Society of Chemistry report [1], and presented to students by the Maths Careers website [2], but a brief summary might be helpful.

Work placements are believed to promote employability by giving undergraduates practical experience of the workplace. They increase students’ motivation by showing them directly how the mathematics they are learning at university is used in industry and commerce. They allow students to sample careers which they might be considering without making a long-term commitment. They provide an opportunity to impress a potential employer and in some cases result in a job offer from the employer after graduation. Perhaps more importantly, in the words of Gillian Stansfield, Placements Tutor for the Department of Physics, Astronomy and Mathematics at the University of Hertfordshire, students “mature and become far more professional in their approach” [3].

Placements have potential drawbacks. Time spent in the workplace may replace classroom or study time, resulting in students learning less mathematics. While many placements result in a student returning to study with increased motivation and enthusiasm, for some it can be difficult to settle back into academic study. And placements are not without risk: placements can break down for many reasons. A student may not be able to cope with the demands of the workplace; a business may fail causing the placement to be terminated before completion. Such a failure can put a student’s degree at risk.

The overheads of placements include dealing with employers, helping students make applications, preparing students for interview, managing the placement and probably visiting the student during the placement, and, for some placements, assessment. Some or all of these activities may be managed centrally within an HEI or at department level.

Departments also benefit from operating placements. They lead to improved links with employers, give academics insight into the present-day workplace, and potentially provide a route to foster employer engagement with the curriculum.

This report provides an overview of three categories of work placement for mathematics undergraduates. The University of Reading’s HE STEM project ‘Workplacements for Maths and Stats Undergraduates’, is carrying out a more detailed study of placements, aiming “to establish a protocol for assessing and accrediting workplacement experiences and activities” [4].

The traditional sandwich placement involves a student undertaking a full year’s full-time placement between the second and final years of their undergraduate study.

The Undergraduate Ambassadors Scheme and other national schemes have provided opportunities for mathematics undergraduates to work in schools during their studies. Since increasingly teaching is an attractive destination for undergraduates, these and other ways in which maths students work in schools can be considered to be industrial placements.

For students who do not wish to take a whole year out of their studies for a sandwich placement, there are increasingly available other forms of placement, such as internships. For example, the University of Greenwich offers a part-time industry placement modelled on the Undergraduate Ambassador Scheme.

These categories are discussed in the next three sections.

Sandwich Placements

The one-year industrial 'sandwich' placement between the second and final years of a mathematics degree is a well-established feature of many degree programmes. Many universities offer sandwich placements to students, usually as an option. Students are usually paid during their placements (an average of about £15,000 at Aston in 2011/12) [5]. Successful completion of the placement may be recognised by a certificate or award supplementary to their degree.

The benefits to students are widely recognised as substantial: some were discussed in the previous section. The University also benefits through closer links with employers, giving insight into how mathematics is used in the workplace and perhaps getting employer input into the curriculum. Employers get enthusiastic, reasonably cheap labour and some can regard a placement as a 'twelve-month interview' in which they can assess a student's suitability for a permanent position.

In most universities a relatively small proportion of students do a sandwich placement, although this varies significantly. For example, at Cardiff 43 students are currently placed (about 33% of the relevant cohort); at Sheffield Hallam about 25% of the cohort; at Aston 15 (about 10% of the cohort); at Hertfordshire 2 (under 2%); and at Greenwich 2 (about 3%) [6] Where numbers are low this is in part because of difficulties in finding placements and in part because of low demand from students. At least some institutions have experienced a significant drop in demand from students over the last twenty years.

There are a number of reasons why students may not wish to do a placement. Increasingly, students have had the opportunity to gain work experience elsewhere during their studies – at many universities most students work part-time during term. Changes in student funding may have incentivised students to finish their degree in the shortest possible time rather than spend an extra year doing a sandwich placement (probably for a lower salary than in the first year of their job after graduation), and students may wish to remain in the same cohort as their friends.

A recent study by Emily Timson [7] identifies three significant barriers to students contemplating placements. Many students have, for family or other reasons, preferences or non-negotiable requirements over the location of a placement which mitigate against finding a suitable opportunity. Some students lack confidence about the likelihood of finding a placement in the current economic climate and are deterred from looking, while others have unrealistic expectations of the level of work they might be doing and don't consider the kind of placements that are realistically available to them.

While many employers are keen to provide opportunities for placements, some have concerns over the administrative burden, and there is competition from other forms of placement, such as internships.

Managing placements is a significant overhead. The management may be centralised or at department level, or somewhere in between, but there will normally be a significant amount of administration for the department. A placements office will maintain links with employers, advertise vacancies, and help students apply. Increasingly, larger companies advertise placement opportunities widely rather than building relationships with a single university, so some universities no longer send students to the same employer each year. Some universities send several students to work for the same local employer: obviously, the university's location is a major factor in the pattern of placements.

While many involved in placements see sandwich placements as providing the best form of work experience, for some students it may not be feasible or attractive. Alongside the gradual decline in sandwich placements at some institutions, there has been an increase in other forms of placement.

Placements in Schools and Colleges

The benefits of students working in the classroom and colleges for school students, undergraduates, universities and for schools and colleges are substantial, and there are now many mathematics departments offering such opportunities. A valuable booklet presenting several case studies has been published by the National HE STEM Programme [8].

The Undergraduate Ambassador Scheme

While mathematics undergraduates have had opportunities to work in schools and colleges before 2002, for example under the Enterprise in Higher Education initiative in the early 1990s, the launch of the Undergraduate Ambassador Scheme (UAS) in that year did much to formalise such placements and make local initiatives sustainable.

The scheme was launched by the broadcaster Simon Singh, with four universities and 28 undergraduates taking part [9]. It was promoted by the Conference of Heads of Department of Mathematical Science (HoDoMS) and endorsed by the report of the Smith Enquiry into Post-14 Mathematics Education [10]. For a short time it was supported by the TDA. Now, 140 departments in many subject areas operate the scheme. It offers a framework for undergraduates to work in schools without pay in a credit-bearing module, together with guidance on selection, training, assessment, special project and other matters. Universities create and validate their own modules based on this guidance.

About 30 mathematics departments in the UK and Ireland offer the UAS to their undergraduates [11]. Naturally there are many different implementations, carrying varying amounts of credit and accordingly different assessments (a reflective report and presentation are part of the UAS template). Usually an academic supervisor from the university will visit the placement and observe the undergraduate in action.

The diversity of approaches to the implementation of the UAS shows that it can be a valuable part of very different mathematics degree programmes. From the Greenwich workshop on 'Placements for Mathematics Undergraduates', it is clear that university and school staff and students value the UAS for many reasons:

- It provides opportunities for undergraduates to sample teaching as a possible career without committing to a year's PGCE study
- It puts young, enthusiastic mathematicians as role models into schools, which may encourage more school students to consider mathematics as a degree choice
- At a time of shortage of mathematics teachers, it provides extra help for schools and colleges
- Teaching mathematics can increase students' confidence in the subject, and thinking about teaching may help students better understand how they themselves learn mathematics
- Classroom experience is evidence of highly-valued employability skills: prospective employers are very impressed by applicants who have handled a class of school students!
- A UAS placement is evidence of commitment to teaching which is essential for students applying for PGCE places
- Some students are offered Graduate Teacher Programme (GTP) places by the school where they did their placement

- Some students who take the UAS for other reasons enjoy it so much they decide to enter the teaching profession, helping address the problem of shortage of mathematics teachers
- Links with schools help universities' outreach activities and helps them recruit the best local potential students
- Academics observing student placements gain first-hand experience of current practice in schools and colleges, which helps them understand the expectations and experience of undergraduates coming to university

There are drawbacks and risks:

- Some academics are concerned that gaining academic credit by spending time in a school reduces the amount of technical mathematical knowledge a graduate will gain during their degree
- Some feel that the UAS does not test 'academic' skills and that it is unfair on students doing project work on advanced mathematical topics that others can gain equivalent credit through the UAS
- Dealing with schools and colleges is resource-intensive, especially when maths teachers frequently change job, meaning that contacts with local schools are hard to maintain
- Having the student assessed by their supervising teacher leads to inconsistency of marking between different teachers and schools, but there should be some input from those who have observed the student in class
- University academics lack the expertise to assess the work of students in the classroom
- Since there is a minimum requirement for the amount of time spent in a school, a student who suffers illness or accident part-way through the placement may not be able to complete it, with possible consequences for their degree
- Reassessment over the summer period, or after deferral, is not straightforward
- The UAS may not be scalable: while it is possible to manage placements for a small number of students, managing a large number and ensuring consistency of assessment is challenging, especially if a small number of staff are responsible for visiting the placements

Some of these concerns reflect differing views as to the purpose of a mathematics degree. One might argue that, when teaching is a profession which attracts so many mathematics graduates, a university module which prepares students for a career in teaching is no less appropriate than a module in cryptography which might prepare students for a career in the UK Government Communications Headquarters (GCHQ). With employability increasingly on the agenda for mathematics graduates, the UAS is a remarkably effective way for students to develop highly desirable skills.

There are ways to address some of these concerns.

- At Portsmouth, a member of the University's School of Education is working with the Mathematics Department to deliver elements of education theory to students doing the UAS in order to bolster the academic content. [12]
- At Kingston, the department sub-contracts the teaching and most of the assessment to the School of Education. [13]
- At Greenwich teachers do mark the students they supervise, but since each teacher has probably only seen one student, they have no basis for comparison: one teacher might give a very good student 10/10 and another only 7/10. So the marks are moderated within the University, involving the course co-ordinator, who has an overall perspective, and the tutor who has visited the placement, to ensure consistency. [14]

Different universities approach the problem of supervision in different ways. Some have a single tutor responsible for all placements, which works very well for small numbers but is not scalable. Others expect every member of the department to visit one or two placements, which is a good way to make lecturers aware how much schools and colleges have changed since their schooldays, but has the consequence that someone may feel that the morning spent travelling to a school and observing a student could have been better spent on research.

The UAS is popular within the sector because the benefits for the undergraduate, the university and the school or college hosting the placement are clear. This makes it relatively easy to find placements. After ten years the scheme is still growing.

Other placements in schools and colleges

While the UAS is unusual in that students obtain academic credit for working in a school or college, there are other routes by which undergraduates can gain classroom experience and many of the benefits listed in the previous section.

The Student Associate Scheme (SAS) was a government-funded scheme whereby students were paid to undertake a short placement in a school. This was usually centrally organised but mathematics students were particularly in demand. This scheme was popular with students and universities but funding ceased and it ended in July 2011.

Because of the shortage of mathematics teachers in at least some parts of the country, schools and colleges are often keen to have mathematics undergraduates contribute to their activities. Some universities have been very keen to take up these opportunities, to promote maths education, to inspire school students to study mathematics and so increase the supply of undergraduates, and to give their students opportunities. Examples include the University of Bath's Maths Communicators ([8], pp. 6-7), Cambridge's STIMULUS scheme ([8], pp. 8-11), and Greenwich undergraduates working in outreach with local schools [15] based on Maths Arcade [16] and FunMaths Roadshow [17] activities. Undergraduates might support homework clubs, revision classes, maths clubs and similar activities. These engagements may be organised by the university mathematics department or by a central outreach team, or by collaboration between these: undergraduates taking part may be paid, and they generally take place alongside the curriculum without carrying academic credit (although the Bath Maths Communicators scheme, which does carry academic credit, is an exception). While these may not be placements in the traditional sense of the term, they deliver similar benefits for the undergraduates who take part.

Other forms of placement

Increasingly there are other opportunities for mathematics undergraduates to gain work experience. These include internships, which may take place during vacations or for a short period during term, work shadow opportunities, and site visits. Since such placements are the subject of the Reading HE STEM project [4], which is investigating frameworks underpinning such placements and processes for accreditation, this report will focus on one particular alternative format which the University of Greenwich has been running for three years.

Greenwich's Mathematics Industry Placement

In 2008 at the time of the last quinquennial review of the undergraduate provision of the Department of Mathematical Sciences, the University of Greenwich suggested that all undergraduate programmes should offer an opportunity for a credit-bearing work placement. The department decided to introduce a 30-credit final year module, Mathematics Industry Placement, based on its implementation of the Undergraduate Ambassadors Scheme but in the context of a general mathematical work placement.

The module requires a student to work for a minimum of twelve-half days (but most do considerably more) in a placement either using mathematics, or where there is the potential to see how mathematics is used in the employer's business. The placement can be paid or (more usually) unpaid.

The department was very much aware that, whereas the benefit to a school hosting a UAS placement is recognised, for many employers this model of placement may not seem very attractive, with the student being of limited effectiveness and the overheads significant. The module was therefore designed to make as few requirements of the employer as possible: an academic supervisor will visit the workplace to discuss the student's performance but there is no employer assessment, and there is no requirement for a "special project" since the University is not in a position to dictate what an employee does for an employer. The module specification [18] is deliberately as unspecific as possible about the nature of the student's work.

The assessment is by reflective logbook, presentation and a report which discusses, in addition to the student's work, how mathematics is or could contribute to the employer's business. This module covers the PDP element for final stage students, which involves career and continuing professional development planning and also requires students to consider how the placement has prepared them for their future career.

Whereas for sandwich placements universities often have a well-established pool of local employers to draw on, the innovative nature of this placement meant that there was no such starting point. The School's Employability Office is able to offer students support in finding a placement, but most opportunities come from either personal contacts or from volunteering. The University's central Guidance and Employability Team (GET) promote volunteering opportunities.

The uptake has been fairly small, with nine students doing placements over the last two years. It is not clear how scalable this operation will be. Examples of placements include:

- A student working for a pub, using the operational research techniques she learned in her second year to make recommendations regarding stock control and applying queuing theory to determine the optimal number of staff to employ at any time
- A student working for a charity dealing with the rehabilitation of prisoners, who used sophisticated statistical methods to evaluate its success in reducing the rate of re-offending, with a possible journal publication resulting
- A student working for a major newspaper publisher, who spent one day in each of several departments and gained excellent first-hand experience of the accounts and circulation operations
- Two students working for small local accountancy companies, doing general reception and office work, including fairly limited basic accounting mathematics

At best, such placements provide real experience of the use of mathematics in the workplace, in addition to some of the benefits obtained from other forms of placement. In 2010/11 two out of five placement students were offered permanent jobs by the company where they were placed. Where students secure less prestigious placements with limited opportunity to apply advanced mathematics, the benefits are less obvious. Students with no previous work experience may considerably enhance their employability by doing a relatively mundane placement, while others who have worked part-time throughout their studies may already have a strong CV in this respect.

Consequently the advice given to students is that they should consider the value of a potential placement in enhancing their CV before proceeding. A placement which offers real opportunities to apply serious mathematics in an industrial context would be valuable to any student (but such opportunities are rare). A student with limited work experience may benefit from almost any placement (and for some students, a family situation made it impossible to do part-time work in any other context so this was the only way they could gain work experience during their studies). Students not in either of these situations are advised that they have little to gain from this placement. Tutors aim to talk through the pros and cons with students before placements are confirmed.

One observation is that some of these placements arise through personal contact, and this is particularly true of the placements which offer the best opportunities for students: these often are arranged through family members. As a visiting tutor, the author of this report was told by one student's supervisor that the company had provided work experience opportunities for several undergraduates, and proceeded to list a number of examples in each of which the undergraduate had been a relative of one of his colleagues. It is not surprising that this is the way that such things operate, especially when the form of placement involved possibly offers limited benefits to the employer. But when one of the aims of such placements is to help students who do not have the right connections to improve their employability, it is ironic that the best opportunities are sometimes available to those who are already well-connected.

One final example illustrates both the dangers and the benefits of this module. A Financial Mathematics student had a placement with a retail company which potentially gave her the opportunity to observe the mathematics of stock control, pricing and accounting. Unfortunately a few weeks into the placement, following a staff reshuffle, the new manager terminated the placement. The student was now potentially unable to complete the 30-credit module.

Fortunately she was able to find a new placement with a third sector organisation, and was able to work for twelve full days during the second term. Although the work, involving managing funding for small charities working with young people, was not deeply mathematical, in the circumstances she had little alternative but to accept the placement. It turned out that she was able to learn a great deal about the financial management of third sector organisations, which interested her so much that she decided to make her career in that area. After graduation, she successfully applied for a permanent position in the organisation in which she had worked as a volunteer, and is now beginning her career there.

Conclusion

This report has looked at a number of models of industrial placement for mathematics undergraduates. In the current financial climate, graduates are often finding that excellent technical skills are not enough to secure the jobs to which they aspire, so placements which give the opportunity to acquire and demonstrate the graduate skills employers require will continue to be highly valued. But in changing times for higher education, departments may wish to consider which models of placement best achieve the outcomes sought by both students and universities.

References

1. Maths Careers website (2011). *Are industrial placements helpful?* Available via: www.mathscareers.org.uk/viewitem.cfm?cit_id=383089 [last accessed May 2012].
2. Royal Society of Chemistry (2012). *Industrial Placements*. Available via: www.rsc.org/Education/HESTEM/EmployerEngagement/Placements.asp [last accessed May 2012].
3. Personal communication, March 2012.
4. National HE STEM Programme (2012). *Workplacements for Maths & Stats Undergraduates*. Available via: http://www.hestem.ac.uk/activity/workplacements-maths-stats-undergraduates [last accessed May 2012].
5. Sudhir Jain, Aston University, personal communication, March 2012.
6. Information kindly supplied by Janet Williams and Rob Wilson (Cardiff), Neil Challis (Sheffield Hallam), Sudhir Jain (Aston) and Gillian Stansfield (Hertfordshire): private communications, March 2012; and Nadarajah Ramesh (Greenwich), *Industry Placements – the Greenwich experience*, presentation at workshop 'Placements for Mathematics Undergraduates', 14 May 2012, University of Greenwich.
7. Emily Timson (2012). *Why don't more students pursue placements?* Available via: www.agcas.org.uk/articles/576 [last accessed May 2012].
8. National HE STEM Programme (n.d.). *Mathematics: Student Ambassador Case Studies*. Available via: www.hestem.ac.uk/sites/default/files/ambassador_web.pdf [last accessed May 2012].
9. *The Undergraduate Ambassadors Scheme*. Available via: www.uas.ac.uk [last accessed May 2012].
10. Adrian Smith (2004). *Making Mathematics Count: The report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education*. Available via: www.mathsinquiry.org.uk/report/MathsInquiryFinalReport.pdf [last accessed May 2012].
11. The Undergraduate Ambassadors Scheme (n.d.). *About UAS: Participants*. Available via: http://www.uas.ac.uk/participants_u.htm [last accessed May 2012].
12. Ann Heal and Susan Gibbs, *Undergraduate Ambassador Scheme*, presentation at workshop 'Placements for Mathematics Undergraduates', 14 May 2012, University of Greenwich.
13. Nigel Atkins, personal communication, May 2012.
14. Noel-Ann Bradshaw, *UAS in Maths Department at Greenwich*, presentation at workshop 'Placements for Mathematics Undergraduates', 14 May 2012, University of Greenwich.
15. Noel-Ann Bradshaw and Karen Holland, presentation at workshop 'Placements for Mathematics Undergraduates', 14 May 2012, University of Greenwich.
16. Noel-Ann Bradshaw and Peter Rowlett, eds. (2012). *Maths Arcade: stretching and supporting mathematical thinking*. MSOR Network.
17. *FunMaths Roadshow*. Available via: www.maths.liv.ac.uk/lms/funmaths/ [last accessed May 2012].
18. University of Greenwich School of Computing and Mathematical Sciences (2012). *Mathematics Industry Placement course specification*. Available via: www.cms.gre.ac.uk/courses/details.asp?banner=MATH1108 [last accessed May 2012].

Acknowledgements

I am grateful to Nigel Atkins, Neil Challis, Paul Glaister, Sudhir Jain, Paul Oman, Andy Osbaldestin, Gareth Parry, Jenny Sharp, Gillian Stansfield, Jeff Waldock, Janet Williams and others who took time to provide information on their University's use of placements in response to my request through the MATHSHEADS email list maintained by the Conference of Heads of Department of Mathematical Science (HoDoMS), to Emily Timson who shared her research findings, and to those who attended the HE STEM workshop on "Placements for Mathematics Undergraduates" at the University of Greenwich on 14 May 2012. Particular thanks are due to Veronica Benson of the University of Reading, Ann Heal and Susan Gibbs of Portsmouth University, and Noel-Ann Bradshaw, Nadarajah Ramesh and Karen Holland of the University of Greenwich, who presented at that workshop, and to all those who took part in the very fruitful discussions at that workshop. Special thanks are due to Peter Rowlett of the MSOR Network for his support, advice and suggestions throughout this project.

7. Supporting progression in mathematics education

James Hind, School of Science and Technology, Nottingham Trent University

This article first appeared in MSOR Connections 11(3), pp. 50-51.

Background

This project involved the creation of a final year project framework based on mathematics pedagogy. This would involve final year mathematics students[1] visiting a local secondary school to observe teaching to GCSE and A-level classes, preparing material in consultation with teachers and delivering this to classes of the appropriate level from the assisting school. This would benefit students interested in progressing from their degrees onto a PGCE course by providing them with insight and experience into the nature of mathematics education and assessment at secondary school level.

The project had the additional goals of addressing stereotypes about mathematics degrees and encouraging secondary school children into mathematics degree programs. The goal was to bring classes to Nottingham Trent University where the lessons could be delivered by the students. In addition, this visit was planned to include: a campus tour; question and answer sessions with staff and students; and, a talk on university life, the nature of mathematics courses and careers. Given the relative gender imbalance in mathematics degree intake it was decided that we would work with a girls' school.

Implementation

The project was made available to all final year students, regardless of gender, but it was made clear that those with an interest in female mathematics education would be prioritised. Two students (both female) applied to do the project and both were accepted.

The Nottingham Girls' High School agreed to participate in the project. This school has results well above the national average and it is usual for pupils there to attend university after their A-levels. While mathematics is a popular subject at A-Level it is usually seen as a useful entry requirement to some other field of study such as science or medicine and not taken as a degree subject itself. It was hoped that the campus visit would be useful in raising awareness of mathematics as a viable degree option.

The two participating students each researched an area of mathematics not currently part of the National Curriculum and developed lesson plans, supplementary materials and assessment tools suitable for GCSE and A-level. One student focused her project on cryptography and the other on fractals. Both topics were thought to be of appropriate mathematical complexity and interesting enough to motivate the school children. To satisfy the requirements of a final year project in mathematics each subject was explored to a greater degree than was presented to the school children.

Two mathematics teachers at the Girls' High School took part, each acting as mentor to a particular student. The teachers were generous with their time and made themselves available by phone and email for consultation with the students. The students attended the teachers' maths classes on several occasions to observe and to assist where appropriate. During the first few months the students began to learn about teaching methods, learning styles, assessment methods and other pedagogic subjects.

---

[1]For clarity, 'students' is used to refer to the final year degree students and 'school children' or 'pupils' to the members of the GCSE and A-Level classes involved.

In addition to writing their project scripts and producing an interim presentation, the two students built up lecture materials including hand-outs, group work sheets, feedback forms and lesson plans. A date was set for the visit and transport and catering was arranged. At this point the project experienced its first hurdle. One of the teachers who had been leading the project at the School end (the head of the mathematics department) was promoted to deputy head at short notice. Unable to spare the time that the project required she was quick to appoint a replacement to continue the project on her behalf.

Further pressure was applied to the project when one of the participating teachers arranged a holiday for the date of the visit. With less than a week to go we had to reschedule the visit. Given the tight timetable for project submission I felt that my first priority had to be ensuring that my students were not disadvantaged by a lack of time to write up the results of their projects. Instead of the school children visiting the campus our students went to visit them and delivered their classes at the school. Further problems were encountered when the rooms we had been told would be used were unavailable on the day. The alternative rooms lacked the expected facilities and this caused some last minute revisions (and concomitant nerves) for the students.

Evaluation

Whilst it was disappointing not to be able to provide the talks and tours that had been arranged, the actual lessons delivered by the students were well received by the teachers and the school children. Feedback suggested that the lessons had been considered to be of high quality by the teachers and interesting by the students. The group work on fractals was especially well received.

The projects themselves were marked, second marked and viewed by our external examiner. All agreed that they were of first class standard. The two students both graduated with first class honours and have been accepted onto PGCE courses. Both are firmly committed to a career in teaching and both show every sign of great promise in their careers.

Discussion, further development and sustainability

The project has been run again this year in a modified form with 4 students. I am working with a variety of schools so we will be less reliant on any single school. Each student is working with at least one unique school and all schools will be invited on the same day for visits.

One unexpected outcome of this project has been talks between our Mathematics and Education departments about a 'Mathematics Education' degree. It is hope that this will be ready (in a limited, pilot form) for 2012 entrants.

8. Being a Professional Mathematician

Tony Mann, University of Greenwich

Chris Good, University of Birmingham

This project aimed to create teaching materials on 'Being a Professional Mathematician' along with guidance as to how they could be incorporated into the undergraduate curriculum. This followed a recommendation at the 2011 HE Mathematics Curriculum Summit [1] that teaching materials be produced to help "develop students' awareness of the culture of mathematics" and "counter a view of mathematics as a static, completed body of knowledge and instead encourage awareness of the process of doing mathematics" (p. 29).

The project set out to present information about mathematical practitioners, mainly from the present day but with some historical examples included. It was decided that the main output would be audio recordings of interviews with contemporary mathematicians, and with historians talking about mathematicians of the past. Audio was felt to be convenient for today's students, for material supplementary to their lectures. Other outputs include worksheets for classroom discussion, suggested titles for essays or personal development planning reflective assignments, and suggested final year projects based around these resources.

Eight mathematicians were selected for the case studies from a call for participants placed in various professional body newsletters and websites in the autumn of 2011, and from personal contacts. These exemplified a wide range of mathematical occupations and levels of experience. They were[1]:

- Danny Brown, mathematics teacher;
- Nira Chamberlain, mathematical modelling consultant;
- Rosemary Dyson, academic applied mathematician, University of Birmingham;
- Peter Furness, mathematics consultant;
- Jay Jobanputra, risk analyst;
- Sue Merchant, operational research consultant;
- Mason Porter, academic applied mathematician, Oxford University;
- Gwyenth Stallard, academic pure mathematician, Open University.

In addition, five historians were interviewed about historical mathematicians. Jackie Stedall (Oxford University) talked about Thomas Harriot, a mathematical practitioner when career paths in mathematics were very different from today. Patricia Fara (Cambridge University) talked about Emilie du Chatelet, whom she describes as "a normal woman and a good scientist". Karen Sylvester (University of Virginia) described James Joseph Sylvester, a great mathematician whose religion was an obstacle to his career. Noel-Ann Bradshaw (University of Greenwich) talked about Florence Nightingale, as a pioneer of statistics. Finally, Tony Mann (University of Greenwich) gave an account of Hugh Everett III, whose career in operational research in the second half of the twentieth century, working both for the military establishment and for consultancy companies he set up, shows the range of options becoming available to mathematicians.

In view of the importance of professional bodies and learned societies for mathematics professionals, representatives of the Institute of Mathematics and its Applications (David

---

[1]Unfortunately an interview with an academic statistician became impossible at a late stage. If she, or another academic statistician, is able to record an interview in the future, it will be posted on the project website.

Youdan), the London Mathematical Society (Fiona Nixon), the Operational Research Society (Louise Orpin) and the Royal Statistical Society (Roeland Beerten) were also interviewed.

The case studies produced involve mathematical practitioners in a range of industrial, commercial and academic fields, and set out to show that mathematics graduates have the opportunity to develop new mathematics in many different contexts in the twenty-first century workplace. Since in many of the interviews the participants talked about the skills required by mathematicians in their field, the need for continuing professional development and the importance of professional practice such as networking, the resources also contain material relevant for those developing undergraduates' understanding of their employability and employers' expectations.

To support the case studies, eight worksheets and other teaching materials have been prepared. These draw on the interviews and on other available sources. The worksheets have been designed to be complete in themselves and could be issued to students for tutorial work exactly as they stand. However, lecturers are free to adapt them to their needs, to extract material from the worksheets to incorporate into their own teaching material, or to create their own exercises around the material. The worksheets are provided in both Microsoft Word format (to allow lecturers to extract material as they wish) and as PDFs.

The worksheet topics are as follows.

- Is mathematics a static body of knowledge or a developing subject?
- The public image of a professional mathematician.
- What makes a professional mathematician?
- The importance of professional bodies.
- What skills do you need to become a professional mathematician?
- Are there equal opportunities in mathematics?
- Role models in mathematics.
- Visual representations of mathematicians.

This project is not about teaching the details of mathematics (though the case studies could be used to motivate and illustrate lectures on some topics in mathematics). Nor does it address the teaching of mathematical thinking, on which there are excellent books by Mason, Burton and Stacey [2] and by Houston [3].

An annotated list of recent biographies and books about how professional mathematicians work is also provided. While it would be unreasonable to ask students to read all of these books, they provide valuable, and often provocative, insights into the culture of mathematicians. They are probably already to be found in most university libraries but would be a useful addition if they are not already held.

The resources created by this project might be used in: PDP (Personal Development Planning); modules on the culture of mathematics, 'mathematics in society' or the history of mathematics; student projects; or, to motivate the study of the mathematics used in the work of the participants in the case studies. A separate booklet [4] gives further details of the case studies, presents the worksheets and discusses in greater detail their possible uses in the HE undergraduate mathematics curriculum.

Some of the material was trialled in a final year University of Greenwich module ('Mathematics in Society') in December 2011 and student feedback was very positive. Preliminary versions of some of the outputs were demonstrated at a workshop 'Being a Professional Mathematician' at the University of Greenwich on 15 May 2012. Feedback from the participants was encouraging, and some suggestions made at that workshop have been incorporated. It is hoped that further feedback will be forthcoming from future users of the resources.

Accessing the resources

All materials produced - audio, worksheets and additional resources – are available via the website www.BeingAMathematician.org which the project team will maintain. The project outputs are intended to be used by lecturers in any way they wish and are released under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License [5].

Providing feedback

We hope that the resources created by this project will prove useful. We would welcome all feedback. In particular, we would like to know:

- How the resources are being used;
- Tutors’ views of the resources;
- Students’ views of the resources.

Feedback can be sent to by email to Tony Mann (A.Mann@gre.ac.uk) and Chris Good (c.good@bham.ac.uk) (contact details as of May 2012; up-to-date contact information will be maintained on the project website).

References

1. P. Rowlett (editor) (2011). *HE Mathematics Curriculum Summit: A report on the summit held at the University of Birmingham on 12 January 2011*. MSOR Network. Available via: http://mathstore.ac.uk/node/1730 [accessed May 2012].
2. J. Mason, L. Burton and K. Stacey (2010). *Thinking Mathematically*. Prentice-Hall.
3. K. Houston (2009). *How to think like a mathematician*. Cambridge University Press.
4. T. Mann and C. Good (2012). *Being a Professional Mathematician*. MSOR Network. Available via: www.beingamathematician.org
5. Creative Commons. *Human-readable Summary of Licence Terms*. Available via: http://creativecommons.org/licenses/by-nc-sa/3.0/ [accessed May 2012].

Acknowledgements

We would like to thank all the mathematicians and historians who generously gave up their time to record case studies, and Noel-Ann Bradshaw and Kevin Parrott who recorded supplementary material for this project. We are also grateful to the participants at the HE STEM workshop ‘Being a Professional Mathematician’ at the University of Greenwich on 15 May 2012, and students on the University of Greenwich module ‘Mathematics in Society’ who trialled some of the teaching materials. The London Mathematical Society provided a venue for some of the interviews. The Universities of Greenwich and Birmingham provided support and we are particularly grateful to Peter Rowlett of the MSOR Network for his advice and guidance throughout the project.

9. Graduates' Views on the Undergraduate Mathematics Curriculum: Summary of findings

Matthew Inglis, **Tony Croft** & **Janette Matthews**, Mathematics Education Centre, Loughborough University

In Winter 2011 we surveyed the views of 428 mathematics graduates from the 2008/9 graduating cohort. Each graduate was asked to reflect on the knowledge/skills they believed that they developed during their mathematical study, and to assess how useful these skills have been during their career to date. We were also able to benchmark these data against an earlier survey of incoming undergraduates' expectations.

Our overall goal was to determine whether the higher education mathematics syllabus adequately prepares students for the workplace.

We found a mixed picture:

- An overwhelming majority of graduates believed that they successfully developed generic cognitive skills during their studies (e.g. logical reasoning, critical thinking and problem solving). Furthermore, there was widespread agreement that these skills are useful in the workplace.
- However, fewer students believed that their studies had developed generic non-cognitive skills such as making presentations, oral and written communication, team working or computer literacy. All these skills were considered to be useful in the workplace, but are apparently not well developed by studying undergraduate mathematics. Furthermore, we found that incoming undergraduates expected to develop these non-cognitive generic skills during their mathematical study, suggesting that there is a mismatch between students' expectations and outcomes.
- When asked to select what skill graduates wished they had had the opportunity to develop more during their mathematical studies, the most commonly selected was "applying mathematics to the real world". Over 90% of incoming undergraduates expected to develop this skill, whereas only around 60% of graduates believed that they had.

This report raises two issues to consider. First, whether the mathematical community is (or should be) satisfied with the range of skills that graduates perceive the current higher education curriculum to develop. And second, if the community is satisfied by the current situation, how the apparent mismatch we observed between incoming students' expectations and graduates' perceived outcomes can be addressed.

The full report can be downloaded from www.mathstore.ac.uk/hestem.

It is important to take account of the needs of employers when developing graduate mathematicians. A majority of students will be looking for employment when they graduate and we should ask ourselves what we are doing to help them in this aim. And for those that enter further study, the skills we hope for in future researchers are not very different to those employers ask for from graduates.

Some of the projects reported in this booklet have worked with employers, employees or professional bodies to develop research findings, good practice advice and curriculum resources to improve graduate skills. Others offer examples of approaches involving employers in delivery of teaching and assessment for work-related learning, and various models that can be used to place students within organisations for work-based learning.

The Mathematical Sciences HE Curriculum Innovation Project was operated by the Maths, Stats and OR (MSOR) Network, working with the Institute of Mathematics and its Applications (IMA) as part of the Mathematical Sciences Strand of the National HE STEM Programme.

www.mathstore.ac.uk/hestem

www.hestem.ac.uk