The six short papers below were presented by their authors at a one-day workshop offered by the Maths, Stats & OR Network in partnership with the Centre for Integrative Learning. The workshop was held at the University of Nottingham on the 23 June 2008.

Introduction

Skills development within an HE degree is emerging as a high-priority area for both government and higher education recruitment. Future investment will continue to be linked with graduate outcomes as identified by a statement from Bill Rammell, then Minister of State for Lifelong Learning, Further and Higher Education: “High-level skills - the skills associated with higher education are good for the individuals who acquire them and good for the economy. They help individuals unlock their talents and aspire to change their life for the better”. The relevance of skills is also highlighted within an extensive DIUS discussion document ‘Higher Education at Work - High Skills: High value’ [1] which identifies “Employers particularly value broad ‘employability’ skills. This is one of the strongest messages from employers to government and is backed by recent research suggesting employers tend to look for graduates who exhibit skills and attributes ….. HE providers, therefore, have a crucial contribution to make and should ensure they are developing and expanding students’ existing cognitive skills”.

Consideration of Science, Technology and Mathematics (STM) has been addressed in two recent reports from the Royal Society [2], [3]. In the first report, graduate outputs are analysed which, in particular, identify the wide-range of career destinations for STM students, many sharing similar career destinations with each other and also a significant percentage with students from other cognate disciplines. The second report addresses ‘fit-for-purpose’ in the next decade and highlights “that in HE we must equip students individually with the knowledge, skills and aptitudes to hold their own with the best in the world”.

As a mathematics community there is an increasing call to enhance, to better articulate and evidence the skills that are, or could be, developed in the study of mathematics-based programmes. The revised Benchmark Statement for MSOR [4] is realistically upbeat on the potential opportunities for mathematics graduates but much remains to be implemented based on the study of ‘Student Employability Profiles’ [5] circulated to employers, that identifies an overwhelming emphasis in MSOR degrees on cognitive skills with limited attention to other competencies. This imbalance is also evident in successive National Student Surveys in terms of personal development (and feedback) by recent graduates from MSOR degrees [6].
In 2006, the Maths, Stats & OR Network, using funding made available by the Higher Education Academy, commissioned the Centre for Education and Industry at the University of Warwick to undertake a small scale study [7] to, amongst other things, identify the skills employers of recent mathematics undergraduates and postgraduates seek. The study approached five companies who were felt to be typical employers of mathematics graduates, and asked them to provide an indication of the types of skills they were seeking, not just mathematical but also basic (literacy and numeracy) and generic skills and abilities. A total of six case studies were produced using a methodology that consisted of structured interviews with graduate recruiters from the five companies.

The study found that, based upon the sample of companies, when they were recruiting from specific disciplines “mathematics and statistic graduates were sought on the basis of their academic qualifications as well as numerical, analytical and generic skills and abilities. In terms of all disciplines, they became part of a pool of graduates from all degrees; where academic requirements were standard and they were assessed in terms of a certain set of competencies”. To investigate this further, the study asked the six graduate recruiters to consider the list of competencies identified within the Student Employability Profiles [5], and rate them on a scale of 1 (crucial) to 4 (not important) to indicate how significant they were in terms of employing mathematics and statistics graduates. Although five of the six companies surveyed indicated their high priority for graduates having particular mathematical skills, only one specifically recruited mathematical sciences graduates; it must be noted that physics, engineering & economics graduates may too possess these same mathematical skills. The findings from the study indicate employers are becoming increasingly reliant upon graduates having particular sets of competencies as well as academic qualifications. The mathematics community needs to be mindful of this when preparing undergraduate programmes and offering careers advice.

Within an increasing emphasis to incorporate skills within the curriculum the Workshop brought together a number of leading practitioners from across HE to identify different ways to help students and staff to recognise, integrate and promote awareness of skills that might be delivered from within an imaginative mathematics programme.

**Vocational Mathematics – a group-project based modelling module**

Stephen Hibberd, University of Nottingham

At Nottingham a third year mathematics degree provision with an emphasis on harmonising strong graduate skills development and application of mathematics is a module entitled ‘Vocational Mathematics’. The module is unique within the curriculum as entirely group-project based and assessed through group-project activities. A major aim is to develop skills and to provide students with experience of the organisational, technical and self/peer assessment requirements of project teamwork. The module is synoptic in bringing together the subject-specific knowledge and mathematical skills attained in the first two years of the course and developing mathematically relevant ‘graduate’ skills. The attributes included are:

- emphasis on group orientated project activities;
- development of skills in and providing experience of the organisational, technical and self/peer assessment requirements of project teamwork;
- harmonisation of the subject-specific knowledge and skills attained in the first two years of the course;
- allowing students to experience significant ‘open-ended’ examples and to develop associated mathematically relevant ‘graduate’ skills;
- the use of two group projects (soon to be extended to three) to give students the experience to improve following feedback and prior experience;
- assessment by oral presentation and report submission, and includes peer assessment and detailed feedback (including video playback);
- provision of an environment in which students can learn from experience and from each other.

The module uses a series of interactive workshops to identify, develop and practice key skills within a group environment both reinforcing the different pedagogic nature of the module and recognising the development of learning outside of a lecture-based environment. Students are also encouraged to reflect and record their experiences using an on-line Personal Evidence Database tool, supported within the Centre for Integrative Learning, to enable students to further synthesise the skills developed within the module and to build up data on their activities and attainments.

The use of two group projects, one of three weeks duration and one of six weeks duration, gives students the experience to work in different teams with extended levels of learning outcomes. Assessment activities of group oral presentation, submission of reports together with peer assessment and detailed feedback, including video playback, promote learning and high-level skills acquisition. Pedagogic advantages of the approach and effectiveness of the learning within the module are facilitated through:

- students experiencing the demands/dynamics of teamwork on a substantial level;
- more demanding projects and shorter timeframes (compared to individual projects);
- more student-led activity and active skills learning;
Developing graduate and employability skills within a mathematical sciences programme
– Stephen Hibberd and Michael Grove

• high quality outcomes;
• effective use of staff and student time.

Student feedback from surveys conducted between the start and end of the module confirms a significant increased confidence in their graduate skills. A summary of the change in students’ perceptions of their key skills from the start to the end of the module is given in Fig 1.

Skills
1. writing a mathematical report
2. making an oral presentation
3. contributing to group discussions
4. working as part of a team
5. expressing problems in a mathematical language
6. interpreting mathematical results in real-world terms
7. interpreting open-ended coursework questions
8. organising material for a written report
9. structuring a written report

Fig 1 – Change in students' perception of their personal skills between the start and the end of the module (2006).

Changing the Undergraduate Experience

Kevin Golden, University of the West of England

The introduction of student fees, the publication of first destination statistics on graduation and the National Student Survey have each contributed to bringing both the value and quality of graduate outcomes into sharp focus. Stimulated by a series of Government sponsored reports into the future direction of the Higher Education sector, which started with the Dearing review of Higher Education in 1997 [8] and most recently saw the publication of the Leitch Report [9], many UK Universities have embarked on programmes that place personal development planning, study skills, workplace skills and employment awareness as an integral part of the undergraduate student experience.

Within this new environment, undergraduate programmes in the mathematical sciences would appear to be well placed to deliver high value undergraduate outcomes. First destination statistics for mathematics graduates place graduate level employment and starting salaries above the national average. However, Hibberd [6] reported that NSS results indicate that mathematics undergraduates do not think that personal development is something that is given a high priority on their programmes. A separate study [7] found that employers may not place such a high premium on mathematics graduates per se, although highly numerate graduates who have strong problem solving skills are valued. It showed evidence that mathematics graduates may come into competition for employment opportunities with graduates from other numerate areas, such as those from engineering disciplines. In a survey carried out at the University of the West of England, employers were asked to rate the skills and attributes they most wanted to see in graduates, assuming that they did have the required level of subject knowledge. While ‘problem solving’ was highly rated (4th), ‘team working’, ‘motivation’ and ‘initiative’ occupied the top three places. The question therefore, is whether it is possible to integrate team working and good communication skills, develop self awareness and critical reflection as part of a mathematics undergraduate experience.

At the University of the West of England, the development of these attributes into mathematical sciences programmes has followed three strands. Firstly, there has been an emphasis on individual and group project work, investigations and communication throughout the programme which culminates in a final year individual project. We also offer students the opportunity to carry out an education based project in a local school. Next, we have strongly encouraged students to spend their third year in industry and currently around a third of our graduates go out on placement. Studies [10], [11], [12] have shown the benefits of a placement year, both to final degree classification and to future employment prospects. Finally, the University has recently implemented its Graduate Development Programme which is delivered locally to each award within the University while adhering to a common framework and set of aims. The overall aim of the programme is to facilitate the personal development of each student throughout the entirety of the award, starting with retention issues, then engagement and motivation, before moving onto issues of performance, satisfaction, employment and lifelong learning. The programme is only in its second year of operation and so it is not possible to state what its effect has been on student performance. It has however, represented a major investment by the University. Students who successfully complete the programme are given a certificate at the end of each year. From the perspective of those of us running the mathematical sciences programmes, it has provided a space to place personal development, team working and critical awareness within the context of a mathematics and statistics programme. To encourage engagement, team working and communication skills in first year students,
we have set up exercises for them to research and present work on a mathematical or statistical problem, for example, Euler’s formula, Fisher’s T-test, the Konigsberg bridge or the nature of infinity. Communication skills are developed through student discussions and informal presentations. Of course students do not always research the problems correctly or fully understand the material. The work does have to compete for time with assessed work from their modules, but the opportunity for the students to try out ideas is valuable. Perhaps, not surprisingly, the most difficult aspect of the programme is to encourage students during the year to be open, reflective and critical in their group discussions. However, at the end of the year students are required to submit a reflective commentary on their experience throughout the year, and here students did provide some interesting insights.

In summary, we have attempted to address the issue of personal development and employability in a way that builds upon the strengths of a mathematical sciences programme, and recognises that all students have high expectations of what a higher education can deliver, not only in terms of an intellectually stimulating experience or an enjoyable time, but also in terms of realising their future potential in what is a highly competitive job market.

Skills modules for mathematics students at Coventry University

Sidney Tyrrell, Coventry University

Skills modules are not universally popular amongst students or staff, despite their importance. You know the feeling? Skills modules kills modules? At Coventry for the last two years we have run a compulsory skills half-module in the first and second year of all mathematics courses, making the passing of these modules a prerequisite for progression. Different members of the Department are involved with the teaching and all see the modules as an important part of our programmes. This is very much a work in progress: imperfect, improving and important.

In the first year the compulsory half module of Professional and Academic Skills (PASS) is for all students on mathematically related courses, and is taught together for 11 weeks in 2 hour sessions in a room with PCs. It is integrated with Induction week and the Personal Tutorial system. Complementing this half module students have to take an Add+vantage half module. These are free choice modules to add skills for employability, and is an important University vision led by the Vice Chancellor.

The first year content of PASS covers:

- Personal skills: Study skills, Reflection on individual learning needs, Personal motivation, and time management;
- Academic skills: Use of the Library portal and subject specific databases; Referencing, introductory use of Minitab and Matlab, small scale sample survey;
- Professional skills: use of Microsoft Word, Outlook, Excel and PowerPoint, File management; working effectively as a member of a group; and written and oral presentations;
- Assessment: is done by an oral presentation in the personal tutorial (10%); Group work: analysing and presenting in PowerPoint the survey findings, (25%) and the presentation of a personal development portfolio which includes evidence of each week’s activities (65%).

What did the students think? The responses ranged from: “To be honest this module contains everything I was hoping to leave behind when I took a maths degree. This module contains presentations and writing more than a title. Both of these things I have spent my entire academic life trying to avoid,” to “I think this module is extremely important for mathematics students as no other module touches on the practices of a real business or work related atmosphere which will be necessary after graduation.”

On the second year compulsory module, Graduate and Enterprise Skills (GRADES) we cover:

- Academic Skills: use of SPSS, LaTex, library skills;
- Professional skills: Project management, CPA Gantt charts; written and oral presentations; Writing of a report to professional standards;
- Personal skills: Maintenance of an online Personal Development Portfolio showing reflection, self evaluation and evidence of personal development over the preceding year;
- Assessment is on Project Management (40%), a written report (40%) and a personal development portfolio (20%).

Student comments included: “This year was similar to last year in that it offered a welcome break from my other mathematical based modules. We concentrate on many different areas all of which have had their interesting parts. I feel this module has helped me develop skills and learn things that to be honest I didn’t think I would learn at university, however I think these skills are useful.”

Using group project work to enhance mathematical and transferable skills

Louise Walker, Senior Teaching Fellow, University of Manchester

Kamila Jooganah, MPhil student, University of Manchester

This article describes a group project course for first year undergraduate mathematics students at the University of Manchester. The course is called the Mathematical Workshop and is taken by about 300 students in semester one.
The course is intended to develop students’ mathematical and transferable skills as well as introduce a broad range of mathematical topics. Inspiration for the Workshop came from working with the Department of Engineering to develop a problem based learning mathematics course. In my own department, project work was left until later in the degree programme. I felt it was important to expose our new undergraduates to project work at an early stage in their university study. The Workshop involves weekly lectures that introduce key ideas for each project. This is followed by a two hour group work session, where students work in groups of about 7 or 8. There are three groups in each classroom with a postgraduate facilitator. The groups work on problems that extend the basic concepts introduced in the lecture. Each problem is designed to encourage students to develop mathematical thinking skills. First the members of the group work through several numerical examples. They discuss these examples and try and spot patterns. They are then asked to formulate conjectures based on their observations. Finally they will try and devise an argument to prove their conjectures. In this way students are encouraged to think like ‘real’ mathematicians. Each project lasts two weeks. The students then write an individual report on the project and they are assessed on their report. As well as including the solutions to the problems, the students have to write a summary of the ideas covered in the project. Marks are assigned for the clarity of their written explanations as well as the correctness of the mathematics.

As well as the project reports the course has an assessed group presentation and an in-class test at the end of term. In the 2007-8 academic year the Workshop has been used in a study of students’ approaches to learning by Kamilah Jooganah, an MPhil student in the School of Education. Research has shown that a traditional lecturer-orientated approach to teaching encourages students to take a surface approach to their learning [13]. This can mean learning by rote, viewing course material as isolated facts and lacking engagement with the course material. In contrast, a student-oriented approach places emphasis on students learning in small groups with a high degree of interaction. This style of teaching has been found to encourage students to take a deeper approach to their learning. Collaborative learning involves students learning from each other. It has been established through research that collaborative learning can be more effective than individualistic approaches. Learning that requires students to discuss their conceptual knowledge and defend their reasoning with their peers enables students to gain a deeper understanding of the course material [14]. Peer discussion and group work, if structured appropriately, can improve students’ communication skills, their ability to delegate tasks, work with others of different abilities, verbally defend ideas to an audience and improve problem solving skills [15 & 16].

Enhancing employability skills through experience: Grasping an opportunity with both hands!
Patricia M. Lumb, University of Chester
Transferable skills valued by employers include team working, project management, presentation skills and report writing. Work-Based Learning and Experiential Learning modules, designed to provide an opportunity to enhance these skills, are well-established at the University of Chester.

At level 2 students follow five 20-credit modules for 20 teaching weeks followed by assessment in these modules. Following this the majority of Mathematics students undertake one of the following options:

1. Work-based learning for academic credit;
2. Global Perspective – Learning from Experience;

(Other options available are International Experiential Learning, Introduction to Entrepreneurial Skills and a Work-based Project Module). Only the Mathematics Experiential Learning is organised by staff in the Mathematics Department (a small department delivering programmes leading to BA/BSc, MSc, MPhil, PhD).

Option 1 (Work-Based Learning for Academic Credit) begins with a support programme (10 hours), prior to the placement, followed by a minimum of 150 hours in the placement (attendance is verified by the placement provider). Mathematics students typically undertake school placements (either locally or in the student’s home town), placements in the Financial Sector or ones involving statistical analysis. Students are expected to (i) work within an organisation (and to become aware of organisational aims, culture and drivers and employer expectations), (ii) fit into a team (and analyse the skills and competencies of the members of their team) and (iii) inform and develop professional practice through application of academic subject knowledge to work-based tasks and projects.

Option 2 (Global Perspective) begins with an orientation/support programme for 15 - 30 hours prior to completing a minimum of 150 hours in the overseas placement. The support programme includes personal and work-related skills such as self management, team working skills, leadership, effective time management and organizational skills, as well as destination specific information (e.g. language instruction if appropriate).

Option 3 (Mathematics Experiential Learning) involves timetabled sessions with module tutors each week but students are expected to manage their own time to complete the tasks allocated to them, to work independently on the individual tasks and to work as part of a team on the group tasks. They are expected to sort out any problems that arise and to seek guidance/clarification.
when needed in order to complete the assessment tasks by the given deadline. In 2008 the students were involved in:

- A marketing project;
- Learning how to use Matlab and Latex (introductory lectures / practical sessions on using Latex and Matlab were given);
- Running Matlab programmes to assist the research of the Mathematics department (all academic staff are research active);
- Producing solutions to worksheets and presenting them using Latex – providing a resource for future students;
- Attending a seminar (on an unfamiliar topic) presented by a visiting researcher from Lisbon (one component of a researcher’s role).

Other typical components of the Experiential Learning module include preparing promotional material, organising a mailshot and mathematical modelling. Individual reports (module reflections) were submitted focussing on:

1. A log of tasks completed - with evidence attached as appendices;
2. Problems encountered - and how they were resolved;
3. Tasks they had led - and how the group responded to their leadership;
4. A review of the contributions made by their peers;
5. What they had learned about the Mathematics Department.

Student feedback is generally very positive. The opportunity to enhance those skills less easily developed in a typical module is appreciated. The 2008 cohort of 10 students felt that the different stages in the marketing project had raised their organisational awareness. The variety of work undertaken by lecturers had surprised them!

Assessment components for these modules (for 2008) are indicated in Table 1. We observe that reflecting on the ‘learning experience’, via a written report/essay, is common to all these modules.

This area of the curriculum focuses on enhancing transferable skills which are clearly valued by employers. The university management’s decision to include such

‘learning through experience’ modules at level 2 provides students with a valuable opportunity to enhance their CV (so important in the competitive search for graduate-level employment) and provides the department with the opportunity to create perhaps an ‘atypical’, but useful, mathematics module.

Personal Development Planning

Mary McAlinden, Oxford Brookes University

Jeff Waldock, Sheffield Hallam University

Personal development planning (PDP) has a central role in helping students to improve their Employability skills. ‘There is a strong relationship between PDP and student employability, and this relationship is central to the development of learners’ ability to identify, articulate and evidence their learning and overall development’ [17].

There are many definitions of Employability, but one that is frequently quoted is from Yorke [18]. Here PDP is defined as: ‘a set of skills, knowledge and personal attributes that make an individual more likely to secure and be successful in their chosen occupation(s) to the benefits of themselves, the workforce, the community and the economy’. A key point is that Employability must be sustainable, i.e., it is about more than helping students into their first job.

Engaging students with the process of PDP can develop skills in communication, planning, time-management, organisation, reflection, self-awareness, target-setting, action-planning and autonomy. Of course, these skills are relevant to all subject areas. However communication skills are particularly important in a discipline such as Mathematics, where students may not get as much experience of creative writing. Three elements of the MSOR Benchmark Statement [4] can be addressed via PDP namely:

- the ability to work and learn independently;
- developing general skills of time-management and organisation;
- general communication skills, writing coherently and communicating results clearly.

Many models exist for embedding PDP into the curriculum (see the references in the web link at the end). Experiences

<table>
<thead>
<tr>
<th>Assessment methods</th>
<th>Work-based Learning for Academic credit</th>
<th>Experiential Learning</th>
<th>Global Perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A learning agreement and action plan</td>
<td>Solutions to a set of problems using Matlab (30%)</td>
<td>Reflective Interview / Dialogue (750 words, 20%)</td>
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<td></td>
<td>(1000 words, 25%)</td>
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<tr>
<td></td>
<td>A critically reflective report</td>
<td>Worksheet solutions produced using Latex (30%)</td>
<td>Briefing Paper (1250 words, 30%)</td>
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<td>(2600 words, 65%)</td>
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<td></td>
<td>An appraisal by their placement</td>
<td>Module Reflection (1500 words) + Marketing exercise (40%)</td>
<td>Reflective Essay (2000 words, 50%)</td>
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<td>(10%)</td>
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Table 1 - Assessment components

Developing graduate and employability skills within a mathematical sciences programme – Stephen Hibberd and Michael Grove
are provided from Oxford Brookes University (OBU) and Sheffield Hallam University (SHU).

PDP at OBU is undertaken by a small number of students in one final-year two-semester module. Students complete specific activities and write short reflective statements based on their experiences of these. PDP contributes 10% towards the overall module assessment.

PDP at SHU is embedded throughout the course. Students complete an online log for each module, weekly in year 1 and every second week in year 2. This is assessed, and contributes towards the coursework component of one module each year. In the final year PDP is required just for the project, and contributes 5%. This year 122 students took part and collectively made over 9,100 PDP log entries.

Some of the key benefits identified by students are: PDP
- improves ability to meet deadlines and become well-organised;
- provides opportunity for assessing and reflecting on understanding;
- improves communication with staff;
- focuses attention on careers.

Our results lead to a set of key requirements necessary for the process to be successful:
- PDP needs to be embedded, and part of core academic activity;
- it should be explained to students why they are doing it;
- the process is more important to student learning than the bureaucracy;
- (all) staff need to be engaged with the process;
- student feedback should be collected and used to improve the process;
- the process needs a key staff ‘champion’;
- academic credit should be awarded!

These suggestions are in line with the HEA recommendations [17].

Further information, together with other relevant resources, can be accessed at http://www.maths.sci.shu.ac.uk/conferencepapers/23June2008/

References

All presentations from the workshop are available online at the following location:
http://www.mathstore.ac.uk/index.php?pid=199


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