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A National Subject Profile for Materials: views of graduates and Materials teaching staff

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ABSTRACT

The UK Centre for Materials Education, on behalf of the UK Higher Education Academy, has undertaken a year-long review of the current state of teaching and learning of Materials programmes in UK Higher Education Institutions (HEIs). The aim was to establish a National Subject Profile for the Materials discipline, providing a "snap-shot" of current Materials teaching in the UK. Part of the study involved a survey of all the UK HEIs who provide significant levels of Materials teaching to allow us to quantitatively map the variety of Materials degree programmes and obtain the views of those who teach Materials on the current challenges they face, in order to identify possible future developments in the teaching the Materials discipline. A parallel survey of recent Materials graduates who have remained in the profession was also undertaken to establish their motivation for choosing to study the discipline, their views of the Materials curriculum they studied, and its relevance to their chosen career. A decline in Materials student numbers, and students facing more external pressures, are perceived as being the two most important challenges faced by academic staff teaching Materials programmes. A large majority of Materials graduates are happy with the content of their degree programme, and its relevance to their career.

1. Introduction and Context

The relatively recent development during the second half of the 20th century of Materials Science and Engineering (MSE) as a taught University discipline was a consequence of a merger of Metallurgy with polymer science, physical and inorganic chemistry, mineralogy, glass and ceramic technology and solid state physics [Cahn, 2001] to include all structural and functional materials. The academic study of MSE, as opposed to the study of the isolated disciplines of Metallurgy, Ceramics, Polymers etc is said to have been initiated in the USA in the 1950s almost simultaneously in the GE research laboratories, the University of California Los Angeles (UCLA), and Northwestern University [Cahn, 2002] The *National Subject Profile* [2008] study, undertaken during 2007, has identified over 100 undergraduate (BEng, BSc and integrated-MEng) Materials-related programme variants currently offered at 21 HEIs in the UK, including 14 BEng and 13 MEng general MSE programmes. At taught-masters postgraduate level, programmes that are considered as being based primarily on the study of Materials are offered at 26 different HEIs, with 14 of these HEIs offering a general (advanced) MSE programme. Most Materials degrees are accredited by professional bodies, primarily the IOM^3 (Institute of Materials, Minerals and Mining) who currently accredits undergraduate Materials programmes at 14 HEIs, and graduates can become recognized as professional engineers.

The Materials discipline's major significance to society is attested by Materials technology being recognised and funded as a key underpinning technology by the UK government's Technology Strategy Board, and reports such as Materials IGT's *A Strategy for Materials* [Materials Innovation and Growth Team, 2006] which stated 'Material businesses in the UK, companies that produce and process materials, have an annual turnover of around £200 billion. They make a major direct contribution to the economy at 15% of the country's GDP, while also underpinning all areas of economic activity. . .It employs some 1.5 million people and supports around 4 million more jobs.' However, the Materials discipline (along with Physics, Chemical Engineering and Chemistry) has been recognised by HEFCE as being both strategically important and vulnerable in Higher Education, and several reviews (including the Materials IGT report) have commented on the lack of an accurate perception of the discipline in society at large, which has resulted in relatively small number of students coming forward to undertake degree level study. This is not a new phenomenon; in 1975 Cottrell [1976] commented that in the UK 'there is still very little awareness of these subjects [Materials and Metallurgy] among the schoolmasters who guide their school-leavers'. Currently only about 0.5% of undergraduate applications to universities for STEM subjects (Science, Technology, Engineering and Mathematics), and 2% of those for Engineering subjects, are to study Materials-related disciplines.

Over the last few decades, recruitment problems to traditional Metallurgy and Materials programmes have led to considerable rationalisation, with a move towards interdisciplinarity and new programmes focussing on, for instance, Bio/medical-, Aerospace- and Sports-Materials being developed at various Universities. The NSP survey of HEIs indicated that currently about 400-500 students graduate each session from all Materials undergraduate programmes, with almost one-third graduating from integrated-MEng Materials degree programme and two-thirds from Bachelor programmes. There are also just over 300 graduates each session from Materials postgraduate taught Masters programmes. The proportion of female students studying undergraduate Materials programmes has increased from just under 20% in 1996 to 26.7% in 2006, with the Bio/Medical- and Sports-Materials programmes attracting both male and female students into the discipline in roughly equal numbers. The proportion of overseas (non-EU) students on all Materials undergraduate programmes has increased from 13.4% to 30.8% over the past decade, with the majority choosing general MSE programmes. The proportion of non-UK EU students has stayed fairly constant at about 4% over the same period. In comparison, about 8 % of Physics undergraduate students and 21% of Mechanical Engineering undergraduate students are non-UK residents.

The complete NSP report [*National Subject Profile for Higher Education Programmes in Materials*, 2008] will be published by the Higher Education Academy. The focus in this paper is on the undergraduate Materials programme provision, specifically the views of academic staff who teach Materials on the challenges they are facing, and the views of recent Materials graduates on their Materials studies and its relevance to their chosen career. To produce the data used in the NSP report and this paper, two surveys were undertaken. The first asked all UK HEIs who provide undergraduate or taught postgraduate Materials programmes to provide information on their curricula, the academic staff teaching Materials, and the views of those staff. The second survey obtained the views of Materials graduates who have continued into the Materials Engineering profession, on a variety of issues including their original motivation for studying Materials and whether they would still recommend the discipline to potential students, their study habits during their undergraduate studies, and their retrospective view of the Materials curriculum they studied.

2. What current challenges face academic staff teaching Materials?

The HEI survey undertaken to inform the NSP report provided information about over 400 academic staff teaching Materials topics on Materials programmes at 17 HEIs. These staff average 11.5 hours of teaching contact-time per week during term-time. Nearly 40% of this teaching contact-time is conventional lecturing, with the remainder fairly evenly divided between tutorial/seminars, laboratory-work supervision, and project-work supervision. Just over half of teaching contact time, on average, involves teaching Materials topics just to Materials students on Materials programmes, with the rest spent teaching Materials to students on non-Materials programmes or students from both Materials and non-Materials programmes simultaneously, or the teaching of non-Materials subjects.

The views of all academic staff teaching on Materials programmes were requested about a variety of issues relating to teaching students on Materials programmes, with the respondent at each HEI asked to provide the collective 'average' view of all Materials academic staff involved with teaching Materials programmes at that HEI. A pre-specified set of potential 'challenges' faced by their Department/School over the last five years which had impacted on the teaching of Materials were rated as being perceived as a 'major challenge', or of 'some significance', or 'not relevant or important'. **Fig 1** indicates that a decline in Materials student numbers, and students facing more external pressures, are perceived as being the most important challenges. Greater administration and teaching loads, and weaker academic background of students are also perceived to be significant. Lack of investment in the infrastructure associated with teaching Materials does not seem to be a major issue of concern.

'CHALLENGES' SORTED BY IMPORTANCE:	average score
Decline in 'Materials' student numbers	1.5
Students facing more external pressures e.g. financial	1.5
Increased administration/QA of teaching	1.3
Students' academic background weaker	1.3
Increased load on teaching staff	1.2
Materials degree/programme restructuring, rationalising	1.1
Motivating students	1.0
Teaching in conflict with research	1.0
Lack of investment in laboratory teaching facilities	1.0
Adopting new teaching methods ie VLE's	0.9
Declining 'Materials' staff numbers / downsizing 'Materials' departments/divisions	0.9
Lack of investment in general teaching infrastructure	0.7
Increasing sizes of lecture-classes	0.6
Materials ceasing to be a separate department/school	0.6
Lack of investment in IT teaching facilities	0.5
Loss of 'service' teaching on non-Materials programmes	0.5
Lack of experience of teaching management	0.4
Increase in 'Materials' student numbers	0.3

Fig 1 Staff views of the challenges faced by their department/school which have impacted on the teaching of Materials over the last five years. Averaged return from all HEI surveys. Rating: 'major challenge' (+2), 'some significance' (+1), or 'not relevant/important' (0).

The perceived decline in the number of Materials graduates is not only a concern for Materials academics. The Government has identified the discipline as strategically important but vulnerable, and Materials industries report continuing problems finding Materials graduates. The NSP study has looked into the changes in student numbers on Materials programmes and found that whilst the total student entry into undergraduate Materials programmes has remained fairly steady, at least over the past decade, there has certainly been a movement away from the 'traditional' general MSE programmes with the shortfall being made up by students studying Bio/Medical-Materials and Sports-Materials programmes instead. Students on the 'traditional' general-MSE programmes are also increasingly coming from outside the EU. However, general MSE programmes still remain the most popular, with an entry of about 200 students per year in 2006 (about 40% of the total student entry into Materials programmes in that year). Postgraduate-taught Masters programmes in Materials are also increasingly providing a source of Materials students and graduates.

Respondents were asked to comment on what had been done to mitigate the impact of the perceived challenges. The decline in Materials student numbers had been addressed in two main ways by HEIs. Six HEIs said they had developed new programmes, or new variants of materials programmes, in order to boost intake. This was reportedly quite successful in a number of cases. Five HEIs also stated that they actively partake in recruitment activities with local schools, with staff making

substantial efforts to visit schools and interact with pupils. A number of HEIs employ dedicated schools liaison staff, marketing officers, or overseas admissions staff to try to boost recruitment. One HEI stated that they have been running Materials master classes, residential courses and CPD programmes for school teachers, and have seen recruitment to Materials programmes boosted significantly.

The problem of students facing more external pressures was identified by most respondents. Some students were reported as having to suspend their Materials programmes owing to financial pressures. With this in mind, three HEIs stated that they were actively considering the introduction of an amount of flexibility into their degree programmes to allow for such situations, and two HEIs had compressed their Materials timetable so that students had free days enabling them to find part-time work.

It is clear from **Fig 1** that a significant number of academic staff feel that the academic background of students arriving at University has weakened. When asked whether the entry-level skills and knowledge of Materials students had improved, was the same, or was worse than 5 years ago, **Fig 2** shows that teaching staff generally feel their Materials students' knowledge of all academic subjects, and students' skills associated with laboratory work and self-learning, have worsened. There is also a greater variation between students' academic abilities. However IT skills have significantly improved, and students appear slightly more aware of their career potential.

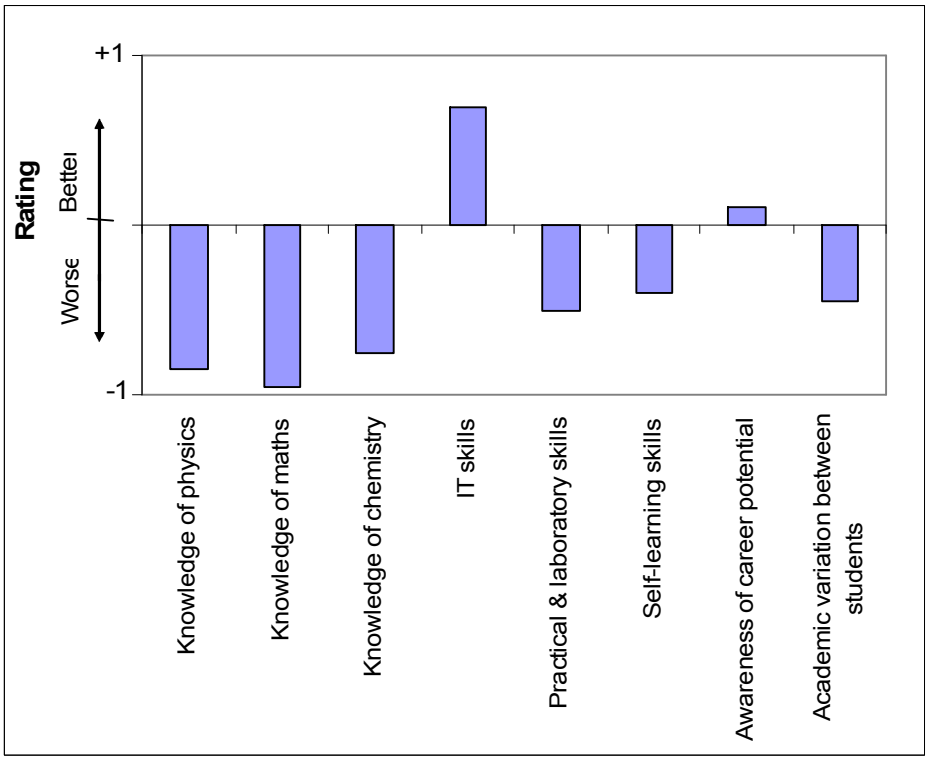

Fig 2 Staff views of the change in UG Materials students' entry-level knowledge and skills over the last 5 years. Averaged return from all HEI surveys. Rating: improved (+1), the same (0), or worse (-1).

The NSP study has found that whilst the great majority (about 80%) of accepted applicants continue to enter Materials programmes with A-level qualifications, the proportion of accepted applicants with an A-level in Maths and/or an A-level in Physics appears to have decreased from just over 60% in 1996 to just under 50% in 2006, with a similar decrease in the proportion with Chemistry A level. This decrease can in part be explained by the increase in the number of non-UK students, many of whom do not take A-levels, and Sports- and Bio-Materials programmes that do not

require both Maths and Physics A-levels. However there were over twice as many accepted applicants who had A levels in Maths, Physics and Chemistry in 1996 compared with 2006, so there has clearly been a need to adapt to the changing knowledge-base of students. Nationally, the number of Physics A-level candidates decreased by 16% between 1996 and 2006, and A-level entries in Maths decreased about 5% over the same period. The NSP study also found that the average tariff score achieved by students entering Year 1 of Materials programmes was 348 points in 2006, compared with an average tariff of 413 for students entering programmes with Physics JACS codes, and 337 for Mechanical Engineering JACS-coded programmes. (However, it should be noted that the JACS data for Physics and Mechanical Engineering may include some students entering undergraduate programmes of study which include an integrated Foundation Year).

The following actions (ordered in decreasing number of respondents) were reported by HEIs as their response to the changes in students' entry-level skills and knowledge:

- Additional introductory/bridging modules were introduced in Year 1, and other modules adjusted to take account of the academic variation between students.
- Increased amount of remedial teaching/tutorial support in maths.
- New/extra modules introduced in experimental- and/or study-skills, and career awareness.
- Drop-in centres/classes introduced to support mathematics and/or English language.
- Those with weak/inappropriate entry qualifications directed to join their programme with an additional Foundation-year.
- Peer-support and peer-tutoring/mentoring schemes introduced.
- Entry grades increased to remove academically-weaker students.

In summary, a variety of strategies are being developed in response to the challenges being faced by those teaching Materials associated with the changing nature of the student body and student experience.

3. What do recent Materials graduates think about their studies and the relevance to their chosen career?

A total of 128 recent graduates (those having graduated since 1998) from undergraduate Materials degrees completed the NSP on-line survey. It had been publicised through various IoM^3 databases and publications, via UKCME contacts, and Materials alumni with the aim of obtaining the views primarily from Materials graduates who had continued into a Materials-related career. There was a 65:35 male:female ratio, with 87% of the respondents being British residents, 5% being non-UK EU, and 8% 'other overseas' students. 89% of the respondents were aged 22-30. 54% of respondents had graduated from a general MSE programme or MSE 'with management/language/industrial experience', with the remainder having studied a variety of other Materials degrees. Of the 128 recent Materials graduates, 87 were in full time employment. Of those who indicated a specific job-title, 18 were employed as 'Materials Scientists', 'Materials Engineers' or 'Metallurgists', a further 23 employed as engineers, ranging from 'Process Engineer', 'Development Engineer' to 'Quality Engineer', and 12 respondents were 'managers'. 15 graduates were post-doctoral researchers, and 4 were University lecturers or teachers.

When asked 'Why did you decide to study for a degree in Materials?', almost all of the graduates indicated it was because the course had appeared interesting, and about half had viewed the career as being attractive (**Fig 3)**. Very few chose the

discipline as a consequence of any advice given at school or by their careers service, perhaps reflecting the lack of an accurate perception of the discipline in society at large e.g. [Cotterell (1976), *Materials IGT* report (2006)].

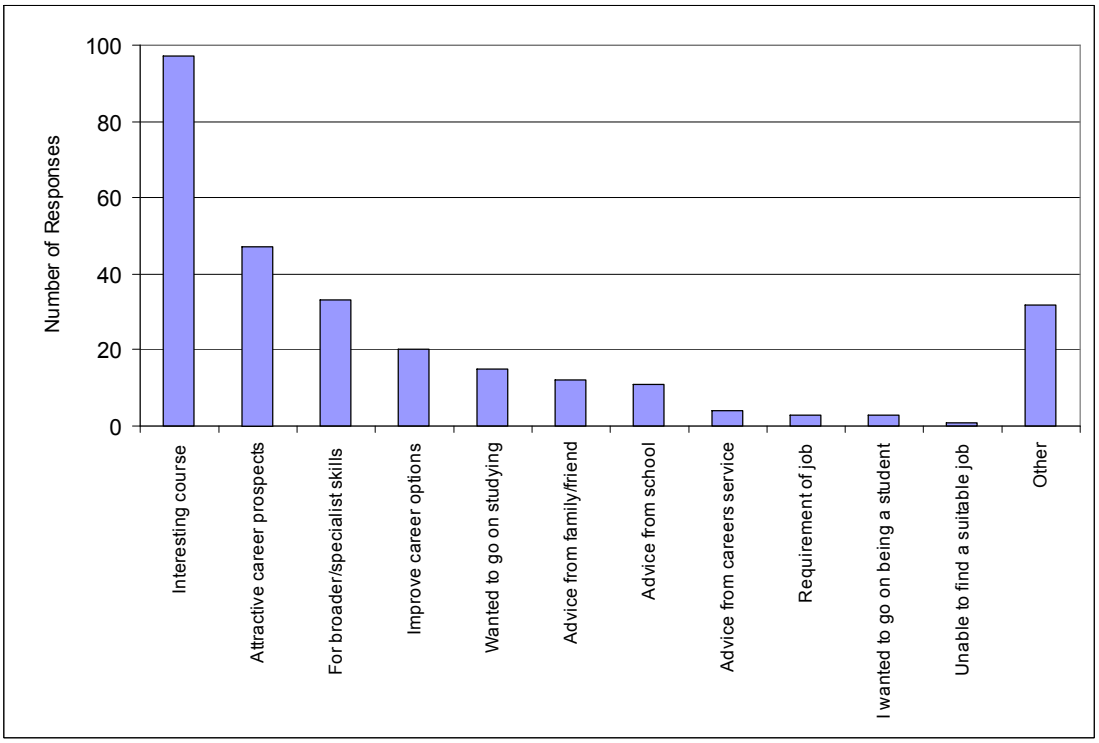

Fig 3 Recent graduates responses to 'Why did you decide to study for a degree in 'Materials'?'. Multiple responses were permitted.

Graduates were also asked 'Do you believe that Materials and Materials-related disciplines are currently a good choice of subject to study at undergraduate and/or taught postgraduate level?'. Respondents were positive, especially in the relevance of their studies to their current career (see **Fig 4)**, describing the Materials discipline as a 'fascinating crossover between physics and engineering and chemistry', and one graduate describing their undergraduate programme as 'an excellent all round course which gives knowledge applicable to many employment opportunities'. Some respondents expressed concern regarding lack of employment opportunities for Materials graduates in the UK, and that some potential employers were not really familiar with the discipline and the skills-set of Materials graduates. However the majority of Materials graduates thought there were still good career prospects and a few specifically commented that there was a shortage of Materials graduates in industry, which had worked to their advantage in terms of career prospects.

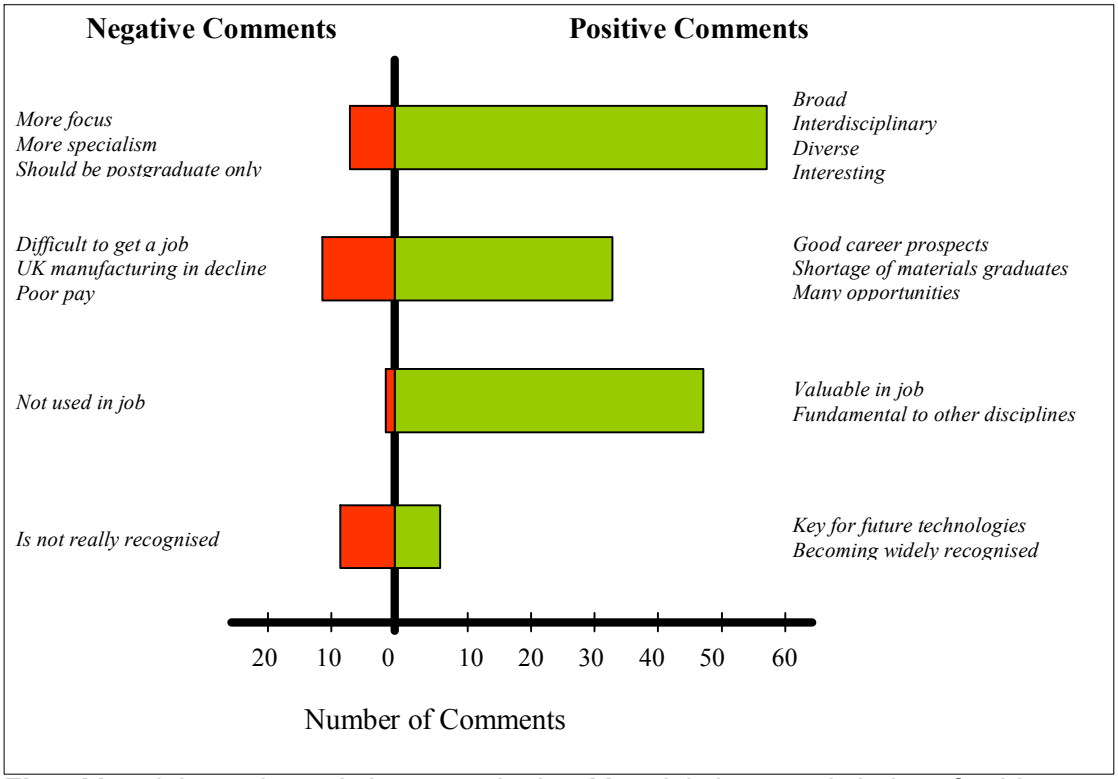

Fig 4.Materials graduates' views on whether Materials is a good choice of subject to study at university. Textural responses were requested, which were categorised in terms of comments related to the nature of the Materials curriculum, career prospects for graduates, relevance to their job, and recognition by potential employers. Representative comments included for each category.

The Materials graduates were also asked about their private study and employment habits whilst on their undergraduate Materials programme. The median number of hours they had spent in private study per week during term-time was 10-19 hours during the first and second years. This agrees with 'The academic experience of students in English universities' study [Bekhradnia et al, 2006] of 15,000 first and second year students which found that the average amount of private study for engineering and technology students, and for physical science students, was just over 12 hours per week in years 1 and 2. The Materials graduates indicated that median number of private study hours increased to 20-29 hours in the third year, and 30+ hours in the fourth year (of an integrated-Masters programme).

What was somewhat surprising compared to previous studies in this area was that only 25-35% of respondents to our survey undertook any form of paid employment during term-time whilst studying for their Materials degree, in all years of study. A previous study of 1500 students of all disciplines found that 53% of students undertook some sort of paid employment during term-time in the last 2 years of undergraduate study [Brennan et al, 2002]. The Brennan study also found that term-time paid employment had a measurable negative effect on student attainment, and adversely affected the ability of students to attend lectures and produce high quality work. It would be interesting to know whether there is a correspondence between low levels of term-time paid employment and continuation into the profession after graduating for Materials and other engineering disciplines.

Finally, Materials graduates were asked to comment on how useful different aspects of the Materials discipline-specific knowledge acquired on their degree programme had been since graduation, and whether they felt that they would have benefited from

more teaching of specific Materials topics. The Materials curriculum was divided into Materials 'subject areas' or 'concepts' based on the QAA benchmark statements for Materials Bachelor programmes, and respondents asked to rank them in terms of usefulness and benefit of more teaching. Responses from all respondents were then averaged and are shown in **Fig 6**.

Materials Subject AreaS	How useful has knowledge been since graduation?	benefit OF more teaching in these areas?	Materials Subject AreaS
'Underlying Science & Eng'	1.48	0.80	'Characterisation of composition & microstructure'
'Mechanical Behaviour'	1.40	0.76	'Mechanical Behaviour'
'Characterisation of composition & microstructure'	1.35	0.74	'Underlying Science & Eng'
'Structure of Materials'	1.28	0.73	'Processing & manufacture'
'Processing & manufacture'	1.16	0.71	'Degradation/durability of Materials'
'Degradation/durability of Materials'	1.06	0.70	'Design with Materials'
'Phase equilibria & phase transformations'	1.05	0.66	'Mathematics'
'Design with Materials'	1.05	0.63	'Sustainability'
'Mathematics'	0.97	0.58	'Phase equilibria & phase transformations'
'Sustainability'	0.67	0.54	'Structure of Materials'
'Extraction'	0.50	0.36	'Extraction'

Fig 6 'How useful' the Materials knowledge in each Materials subject area has been to Materials graduates since graduation, and the benefit to graduates of 'more teaching' in each subject area. A ranking of 'Essential' (=2), 'Desirable' (=1) and 'Not useful/did not study' (=0) was used to indicate 'usefulness'. A ranking of 'Yes, a lot more' (=2), 'Yes, a little more' (=1) and 'No' (=0) was used to indicate the perceived benefit of more teaching in each subject area.

Many Materials graduates find the 'underlying science and engineering' knowledge particularly useful during their early career, closely followed by 'mechanical behaviour' and 'characterisation of composition and microstructure'. 'Sustainability' and 'extraction' and 'mathematics' are topics that recent graduates either did not study much, or have not found particularly useful. When asked *'Would you have benefited from more teaching in this area?'* Materials graduates generally felt (perhaps unsurprisingly) that those subjects which had been most useful to them were the ones which they would have most benefited from additional teaching. However they appear to be generally satisfied with the amount of teaching they received in each of the subject areas. (Materials graduates' views of workplace skills, abilities and attitudes developed during their studies, and the relevance of these to their graduate career, is reported elsewhere [Taktak et al, this Conference].

Conclusions

As part of a National Subject Profile study for the Materials discipline, the views of staff teaching Materials, and recent Materials graduates, have been obtained. A decline in Materials student numbers, students facing more external pressures, greater administration and teaching loads, and the weaker academic background of students are perceived as being the most important challenges faced by Materials academic staff. The NSP study has found that the total student numbers on Materials programmes is stable, but there is evidence for a shift away from single-discipline programmes towards combined Materials programmes for instance with biomedical or sports disciplines. Various strategies have been developed to face these challenges, which are discussed. A survey of recent graduates (mostly in industry) reveals that a large majority are reasonably happy with the content of their degree programme and offers some guidance on the relative importance in employment of the Materials topics studied.

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