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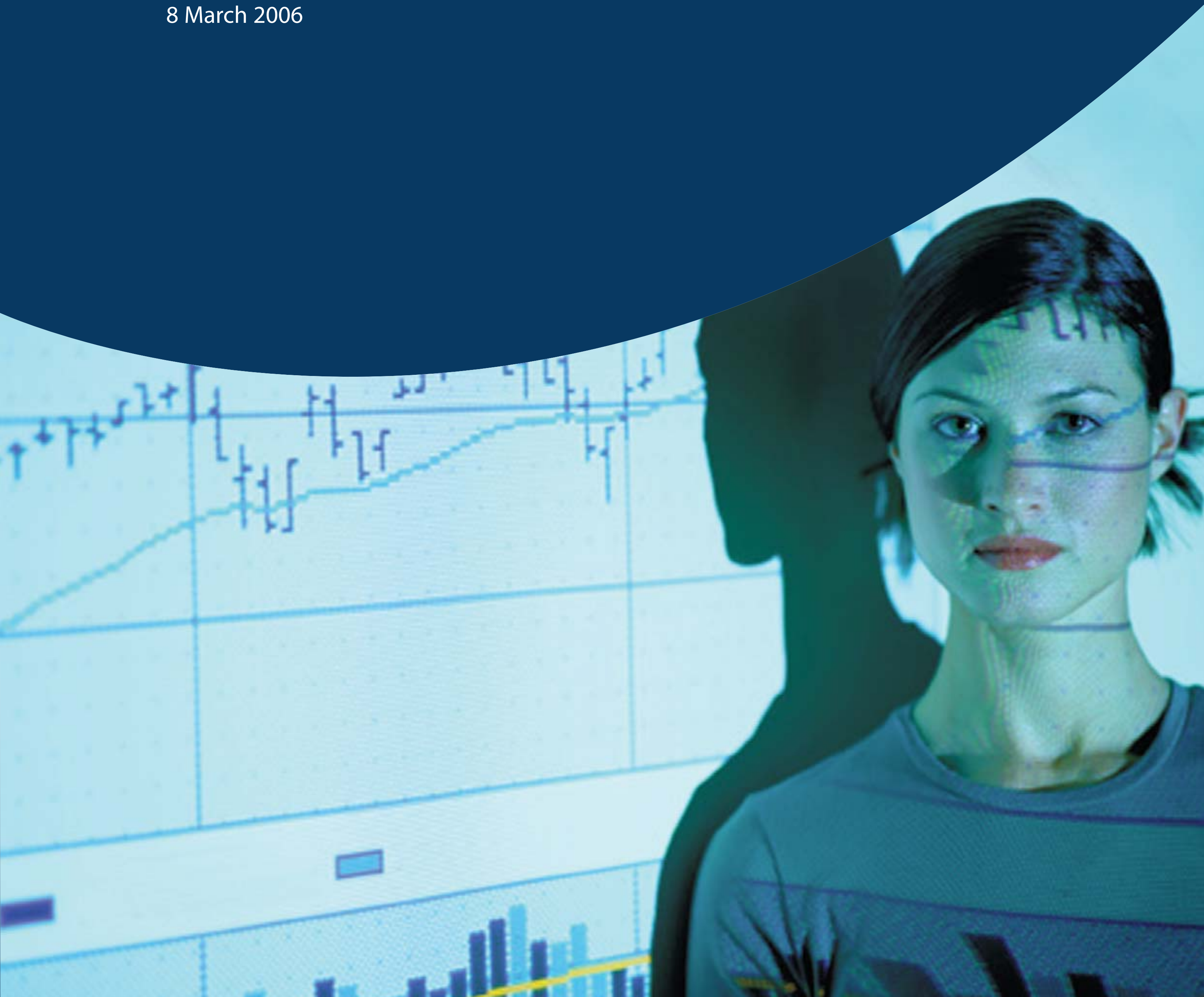
Educating Engineers for the 21st Century: The Industry View

A study carried out by Henley Management College
for The Royal Academy of Engineering
by Nigel Spinks, Nick Silburn and David Birchall

8 March 2006



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Executive Summary

This report presents the results of a study undertaken by Henley Management College on behalf of the Royal Academy of Engineering to investigate UK undergraduate engineering education requirements in terms of the current and future needs of the engineering industry. The research was based on a combination of in-depth interviews with industry practitioners, focus groups with recent graduates, and a large-scale survey of firms within the industry.

The Engineering Graduate Today

Newly-recruited engineering graduates are used in a wide range of job roles. Whilst research and development, design and production/manufacturing are the most prevalent activities within the sample studied, engineering graduates are to be found across the product lifecycle and throughout the value chain. As a result, many graduate engineers are likely to find themselves in roles which do not necessarily involve hands-on specialist engineering. To fill these roles engineering firms look for skills and attributes in two broad areas. The first is a set of defining skills that are unique to the engineer and which encompass the domain of technical skills. These include a sound knowledge of the engineering fundamentals within their discipline, built on a solid base of mathematics. Other highly sought-after attributes in this domain are creativity and innovation plus the ability to apply theory in practice. The second skill set includes the social and interpersonal skills and attributes that enable the engineer to operate in a commercial working environment. These include communication skills, team-working skills, and business skills, which for entry-level graduates primarily mean awareness of the commercial implications of engineering decisions.

Engineering firms use a wide range of methods to attract and develop the engineering graduate talent they need. Although advertising is the most widely used approach, many companies work closely with universities to identify suitable candidates Work placements also play an important role in the recruitment process and candidates who have gained relevant work experience while at university are more attractive than candidates without such experience. In terms of skills development once in work, whilst nearly one-third of companies have no formal scheme in place, 70% of firms do offer some type of formal graduate development programme.

The Quality of Engineering Graduates

Overall, respondent firms report that they are neither satisfied nor dissatisfied with their ability to recruit appropriately skilled engineering graduates from UK universities. There is some evidence, however, both of skill shortages (where there is a lack of appropriately qualified graduates available to be recruited) and skill gaps (where there are particular deficiencies in the skills of those graduates that are available) in the UK graduate engineering labour market, although the picture in the latter case is rather mixed. There is also concern that the grade of degree awarded can be a poor indicator of a graduate's actual abilities. The research also shows that firms recruit engineering graduates from overseas universities both as a response to specific skill shortages and in order to support their overseas operations. In terms of quality, the research concludes that the best UK graduates are probably broadly comparable globally, although it notes the high quality of those engineering graduates from overseas universities that UK firms do encounter.

The research findings also indicate a tight labour market for high quality engineering graduates. In particular, the research raises concerns in three areas. Firstly, firms report that skill deficiencies impact across a range of their activities, including increasing recruitment costs, delaying the development of new products, and restricting firm growth. Secondly, firms adopt a number of strategies in response to perceived skill deficiencies. These include 'upskilling' by increasing training, 'inskilling' through intensified recruitment efforts, and 'outskilling' through the use of third parties, including those overseas, to undertake skilled work. Thirdly, the research has revealed concerns over the long-term pipeline of young talent going from schools onto university engineering courses and subsequently into engineering firms.

Industry Differences

Although there is considerable homogeneity overall in the views of the firms taking part, the research includes a closer examination of two particular groups of firms in order to understand better their particular needs and experiences. The first group is the small- and medium-sized enterprise (SME) sector. The findings suggest that SME engineering firms look for graduate engineers to have broadly similar skill sets to those sought by larger firms, although for some companies, prior work experience is seen as essential. The latter requirement manifests itself in the recruitment by some SMEs of 'post-experience' graduates who have completed 1-2 years of industrial work. Examination of the differences between SMEs and larger firms indicates that smaller firms are less likely to recruit engineering graduates direct from university. Within the sample studied, smaller firms were also more likely not to recruit recent graduates, whether directly from university or as 'post-experience' hires. The research finds no significant difference, however, between SMEs and larger companies in overall satisfaction with their ability to recruit graduates either direct from university or after 1-2 years' work experience.

The second group is the university spin-out sector. As these businesses are set up to exploit university intellectual property (IP) their use of engineering graduates is focused very much on research and development to bring the IP to market. Whilst such firms would like to have graduates with some commercial experience, their technical capability is perhaps seen as of greater importance. This is illustrated by the fact that there is a higher proportion of PhDs recruited to such businesses, and direct from university. At initial start-up, the business lead in such organisations tends to be an individual from a very commercial background enabling engineers to focus on the technical aspects. Despite this emphasis on technical ability, team working and communication are still seen as important skills. Unlike other segments, spin-outs appear to maintain a very close working relationship with their parent university, indeed many continue to make use of research facilities and research students. There is also evidence that where engineering expertise is lacking, resources are bought in from other providers as and when needed.

Future Skills Needs

The research finds that the pace of change in the industry is expected to intensify in both the technological and non-technological domains. Particular themes that emerge include an increased need for firms to focus on solving customer problems; a growing requirement to provide system solutions to those problems; and the increasing complexity of the management task. This management complexity is paralleled by growing technological complexity and interdependence at all levels. Another important factor is globalisation which will continue to affect both the demand and the supply-side of the industry. In particular, the rapid growth in placing work offshore poses a real challenge that will force UK engineering in all areas to concentrate on higher value-added activities. As a result, there will be a premium on innovation and creativity to respond to the challenges of this turbulent environment.

In terms of future skills needs, the research indicates that engineering firms expect an increase in the proportion of graduates in their workforce over the next ten years. Certain disciplines, including electrical/electronic and systems engineering are seen as particularly likely to be of increasing importance. Looking at particular skills and attributes, there is strong evidence that the top priorities in terms of future skills will be practical application, theoretical understanding, and creativity and innovation.

In investigating the link between firms' expected future position and their future skills requirements, the research identifies three groups of companies each of which envisaged different future scenarios. One group can be described as global goods suppliers, focused on manufactured products and globally networked. A second group is service focused but still global. A third group has a more local orientation. The firms in these three groups differ in their demographic characteristics. In particular, the third group tends to consist of smaller firms that are less likely to recruit recent graduates. Those graduates that are recruited by such firms are less likely to find themselves in roles such as design or research and development. In terms of future skills, however, all three groups have similar priorities: practical application, theoretical understanding, and creativity and innovation being priority skills in the future. Service-oriented firms, however, also place a high emphasis on team-working abilities.

To ensure that suitably skilled engineering graduates are available in the future, the research suggests the need for enhancing courses in terms of their development of practical skills but not at the cost of losing a strong theoretical base. Softer skills also need to continue to be included in engineering courses to prepare students for the reality of the workplace. More relevant, business-oriented project work and significant work experience in an engineering environment are suggested as two mechanisms by which these skills can be developed before graduation. Also required are closer university-industry ties and continuing commitment by industry to ensure that good practice is shared and to ensure that the brightest and best youngsters are attracted into engineering.

The Engineering Graduate in the Future

The research synthesises these findings into a picture of the graduate engineer of the future. At the heart lie the defining and enabling skills that form the core competencies of the engineering graduate. Whilst other professions will have special skill sets, it is this particular combination of skills that marks out the engineering graduate and underpins the roles that industry will need such graduates to undertake. Three such roles are identified. Firstly the role of engineer as specialist recognises the continued need for engineering graduates who are technical experts of world-class standing. Secondly, the engineer as integrator reflects the need for graduates who can operate and manage across boundaries, be they technical or organisational, in a complex business environment. Thirdly, the engineer as change agent highlights the critical role engineering graduates must play in providing the creativity, innovation, and leadership needed to guide the industry to a successful future. This is a vision of the future that underlines the vital importance of undergraduate engineering education to the UK engineering industry. At the same time, however, it emphasises the reciprocal responsibility of the engineering industry in ensuring the future excellence of undergraduate engineering education in the United Kingdom.

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Part One: Introduction

1. Introduction to the Research

The number of entrants on to undergraduate programmes in the United Kingdom has risen from just under 230,000 in 1994 to 320,000 in 2004. Despite this rapid growth in the total undergraduate population, acceptances on undergraduate engineering and technology courses have kept fairly static at around 24,500. Of those graduating as engineers, less than half will actually take up an engineering career (ETB, 2005) raising concerns about the supply of new graduates. There is also disquiet over the age profile of the profession (SEMTA, 2004). Doubts over the standard of mathematics in the UK education system add to such concerns (Lea, 2002). At the same time, demand for engineering graduates is expected to continue to grow. As a result, according to one prediction, there will be a cumulative shortfall of indigenous engineers in the UK exceeding 100,000 by 2010 (Hodgson et al., 2004). The possibility of such a skills shortage needs to be understood in the light of the importance of skills to economies, industries, firms, and individuals alike (Crouch et al., 1999, Hogarth and Wilson, 2001, Tamkin, 2005) and the continued emphasis on skills and education by policy makers in the UK and elsewhere (for example DfES, 2005). It also raises serious concerns for the longer term future of the engineering industry in the UK, for example with regard to its research and development capabilities (RAEng, 2003).

1.1 Aims and Objectives of the Research

It is against this background that Henley Management College has been commissioned by the Royal Academy of Engineering (RAEng) to carry out research to investigate the provision of undergraduate engineering education from an industry perspective. The research sets out to establish the extent to which UK undergraduate engineering education fulfils the current and expected future requirements of the engineering industry. In order to achieve this overall objective, the research was broken down into two phases.

Phase One explored the views of engineering industry experts from a range of firms along with the views of recent graduates, through a combination of in-depth interviews and focus groups. Phase Two investigated the views of the wider engineering industry by means of a questionnaire survey. The specific objectives of this research were to establish the existing engineering graduate skills requirements of industry, identify any issues with the quality of current UK engineering graduates and the provision of engineering undergraduate education, identify future skills requirements of the engineering industry, and suggest areas of improvement for undergraduate engineering education in the UK. This report presents the findings of the research.

1.2 Structure of this Report

This report is divided into six parts

- Part One (this section) provides the introduction to the research and addresses a question that has both practical and theoretical relevance, namely whether it is appropriate to talk in terms of graduate 'skills'. Whilst the answer is in the affirmative, acknowledgement is given to the controversy in this area.

- Part Two describes the design for both phases of the research, including sampling, data collection, and data analysis.

- Part Three is the first of three sections that present the findings of the research. The focus of this first section of the findings is on the present: what industry needs from engineering graduates today, and to what extent those needs are being met. This firm-level view is complemented by a discussion of the findings of the focus groups with recent engineering graduates.

- Part Four continues with the presentation of research findings but looks at the questions from the perspective of two particular constituencies within the engineering industry, namely small- and medium-sized enterprises (SMEs) and recent start-ups, exemplified in this case by technology spin-out companies from universities.

- Part Five concludes the research findings by looking at the needs of the engineering industry over the next ten years. It begins with a review of anticipated future trends and identifies three groups of firms with different expectations of the future. It then looks at what these developments mean for graduate engineering skills, before bringing together some industry views about what should be done to undergraduate education to ensure those skills will be available.

- Part Six begins by discussing limitations of the research and factors that need to be taken into consideration when reading the findings. Finally, the Conclusions chapter discusses the conclusions reached on the evidence presented in this report.

2. The Skilled Graduate

This research links together the concepts of skill and undergraduate engineering education but is this a legitimate linkage? One problem in answering this question is the complexity of the notion of skill, which has been conceptualised in different ways by different academic disciplines without agreement being reached (Ashton et al., 1999, Spenner, 1990, Stasz, 2001). Thus skill has variously been seen as an attribute of the individual, an attribute of the job, or an attribute of the institutional setting (Noon and Blyton, 2002). It is also clear that the meaning of skill has changed over time, at least as far as the UK policy debate is concerned (Payne, 2000). This extension of meaning has been challenged, both in its general usage, and in its specific application to higher education. This section reviews that debate and positions the current research within it.

2.1 Skill Talk

One view associates skill closely with ideas of practiced ability (Green, 1994: 38), and therefore with activities that are routine. According to this view, a skill is something that necessarily has to be actively developed, learned or acquired, as opposed to being an automatic physiological response. This view downplays the importance of context, treating a skill as an 'isolatable, discrete ability' and one 'minimally involved with understanding' (Barrow, 1987: 191). This behaviourist interpretation (Hinchliffe, 2002) thus sees skill as 'something relatively routinisable, low in cognitive content, something typically learned through rehearsal' (Bridges, 1993: 44). Examples of skills defined in this way might include drilling a hole in a metal plate or touch-typing. Traditionally it has also led to skill acquisition being linked to 'training' as opposed to 'education', with the latter being associated with the development of knowledge and understanding rather than with routine skills (Assiter, 1995b, Bridges, 1993). The significance of conceptualising skill in this way is that it tends to rule out treating high-level cognitive activities as skills (Hinchliffe, 2002) and consequently using the term in higher education. Against this rather narrow view, which separates skill from knowledge and understanding, Griffiths (1987) argues that the ordinary language concept of skill is in fact inextricably linked with ideas of knowledge and understanding as well as with practical action. Current language use embraces a range of activities from those with relatively low cognitive content, such as planing wood, to those with a high cognitive content, such as running a meeting, teaching a class, or performing surgery (Bridges, 1993). Reflecting this broader reading, Griffiths argues that skill 'is practical knowledge that sometimes requires very little reflection or knowledge of theory, but that sometimes requires a great deal of both' (1987: 210).

2.2 Skill and the Policy Debate

This broader view is evident in the long-running debate over skill within UK public policy. Over the last fifty years the word has moved from having a relatively narrow association with technical and craft skills to being an umbrella term covering a mixture of 'knowledges [sic], capabilities, traits, and physical attributes' (Keep and Mayhew, 1999: 10). Whilst in the 1950s and 1960s, skill was largely conceived in terms of the highly-qualified, analytical capabilities of the scientist and of the technical knowledge and manual dexterity of the technician and craft worker (Payne, 1999) by the 1980s it had broadened to include 'life and social skills' (Manpower Service Commission, quoted in Payne, 1999: 355). This approach is now embedded in the concept of 'key skills', which a recent UK Government report describes as a 'range of essential generic skills that underpin success in education, employment, lifelong learning, and personal development' (DfES, 2004: 6).

2.3 Skills and Higher Education

The idea of such key skills has been carried over into the area of higher education (Whitston, 1998). The Dearing Report, for example, concluded that 'employers want graduates to have a wide range of skills, such as those personal and cognitive capabilities that people use to carry out a wide range of tasks'. It went on to argue that 'four skills are key to the future success of graduates whatever they intend to do in later life' (Dearing, 1997 emphasis in original). The four skills identified were communication, numeracy, the use of information technology, and learning how to learn (Dearing, 1997). More recently, another UK Government report argued that 'we need to ensure that all graduates… have the right skills to equip them for a lifetime in a fast changing work environment' (DfES, 2003: 44). At least within the context of UK Government policy, skill is certainly a concept seen as applicable to higher education.

Both the changing meaning of skill and its application to higher education have been the subject of controversy (see, for example, Assiter, 1995a, Barnett, 1994, Bridges, 1993, Griffiths, 1987). For a commentator such as Barrow (1987), who refers rather disparagingly to what he calls 'skill talk', the (for him) indiscriminate use of the word in expressions such as 'intellectual skills', 'social skills', and 'interpersonal skills' represents an unwelcome extension of the term. Those seeing skill in a broader sense have been less hostile. Bridges, for example, whilst emphasizing the action-orientation of skill, argues that the issue is 'not so much a crude attempt to replace the goals and curriculum of a liberal education by narrow vocational training but a more subtle attempt to supplement or extend them in the interests of ensuring the practical competence or capability of students' (Bridges, 1993: 44). Similarly, building on the concept of skill as practical knowledge, Griffiths (1987) stresses that some skills cannot be developed without reflection and theorizing, so that higher education should be both skill- and theory-based. Hinchliffe (2002) argues for a view of skill that recognizes the importance of situational understanding and of personal agency and claims that such an approach renders skill an appropriate concept for application in higher education.

The current research, whilst acknowledging this ongoing debate, takes a broad view of skill that includes both behavioural tasks (such as operating equipment) and cognitive processes (such as problem-solving) (Peterson and Van Fleet, 2004). This position is in keeping with the thrust of current policy within the UK and in line with other studies in engineering (e.g. Connor et al., 2000, Spinks et al., 2004). It is also consistent with its application in the context of higher education. Thus skill is taken here to include the combination of knowledge, manual and cognitive ability, and attitudes that may be required for effective performance under varying conditions in the workplace. This definition informs both the overall research design and the specific questions asked of research participants.

Part Two: Research Design

Part Two of the report focuses on the research design. It describes the methodology used for the research and provides an overview of both the primarily qualitative approach used in Phase One and the mainly quantitative methods used for the survey in Phase Two.

3. Research Methodology

In order to address the aims and objectives outlined in the introduction, the research was split into two main phases. Phase One initially involved a series of in-depth expert interviews with experienced industry practitioners to canvas their opinions about current and future skills requirements, the quality of engineering graduates, and what improvements they felt were needed to undergraduate engineering education. These expert interviews were conducted in three stages. The initial series of interviews were with managers in large engineering companies. Subsequently these were supplemented by a smaller set of in-depth interviews with representatives of small- and medium-sized enterprises (SMEs) and a second tranche of interviews with key informants involved in university spin-outs. Concurrently a number of focus groups, made up of recent engineering graduates, were conducted to look at similar overall themes but from a graduate perspective. The techniques used for the first phase were those typically associated with qualitative research design, where an iterative approach to data collection and analysis is common (Miles and Huberman, 1994). Phase Two of the research (which overlapped, in fact, with the final series of in-depth interviews) involved a large-scale survey of engineering companies to develop more generalisable data on the topic area. The methods used in this phase of the research were primarily quantitative, including statistical analysis of the findings. This chapter describes each phase in more detail.

3.1 Phase One – The Expert Interviews

This sub-section describes the expert interviews that formed the core of the Phase One research. It is followed by details on the additional interviews that were carried out subsequently and a description of the focus groups with engineering graduates.

3.1.1 Sample Details

Initially, eighteen in-depth interviews were carried out during July and August 2005 with executives from larger companies representing a cross-section of the engineering industry in terms of industry sector and business scope. The interviewees had experience of the recruitment and/or management of engineering graduates. For one multi-divisional company, further data were available in the form of written responses to the questions in the interview schedule from five of the company's business units. These responses were also incorporated into the analysis. In addition, interview summaries were available from three interviews carried out by the RAEng. The companies represented are shown in Table 1 below:

Company		
	ABB	Nortel
	BOC Edwards	Arup §
	BP plc*	Renishaw plc
	BT Group (2 separate interviews)	Rolls Royce plc*
	Defence Science and Technology Laboratory	Shell UK Exploration and Production
	Filtronic plc*	Siemens UK
	Ford Motor Company Ltd	Smiths Group plc
	Foster Wheeler Energy Ltd	Thales UK plc §
	IBM	Thames Water
	National Grid	Atkins §

§ = indicates two participants in the interview * = interviews carried out by RAEng; interview notes used for analysis

Table 1 - Companies Consulted in the First Round of Expert Interviews

A breakdown by sector is given in Figure 1 below:

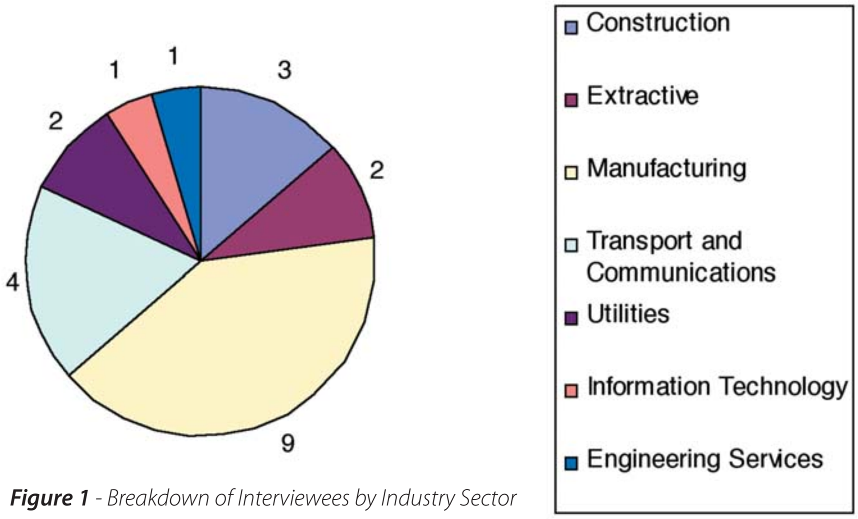

Figure 1 *- Breakdown of Interviewees by Industry Sector*

Figure 1 should be taken as a general guide only since several of the respondent companies were active in multiple sectors.

The majority of interviews lasted for approximately one hour. Five interviews were conducted over the telephone, the remainder were carried out face-to-face at the interviewees work location. The participants, telephone and face-to-face, consented to be recorded for later transcription.

3.1.2 Data collection – Interview Schedule

The interview questions set out to establish the extent to which undergraduate engineering education fulfils the current and future requirements of industry. The four broad themes were:

- Current engineering graduate skill requirements of the industry
- The quality of engineering graduates from UK universities
- Future changes in the engineering industry
- Engineering graduate skills requirements of industry in the future

Additional questions were developed to explore each of these areas further. A summary of the final interview schedule, showing the main questions asked, is attached as Appendix 1. During the interviews, probing questions were asked when it was felt necessary to explore a topic in more depth, or to clarify a particular issue.

3.1.3 Data analysis – Expert Interviews

All the interviews were transcribed in full, generating in excess of 250 pages of data. In addition, interview summaries were provided by the RAEng for interviews carried out by RAEng staff with BP, Rolls Royce, and Filtronic. The approach used was a form of thematic analysis, involving the systematic coding of the data around emerging themes. The process was facilitated by using ATLAS.ti, a specialist qualitative data analysis software program. The codes used in ATLAS.ti to analyse the interview transcripts were developed based on a combination of the original interview questions and themes emerging from the data. The analysis process involved reading through the text and identifying segments of the data which corresponded to specific themes. These segments were then coded accordingly for subsequent retrieval and further analysis. Where appropriate, quotations have been extracted from the interview transcripts to illustrate points made in the report.

3.2 Extending the Sample - SMEs

The initial sample of expert interviews, primarily based on larger engineering firms, was intended to generate data from companies with extensive experience of engineering graduate recruitment. Whilst this objective was certainly achieved, as the interviews proceeded preliminary analysis of the data suggested that SMEs' experiences might be different in certain respects (see Part Four for a discussion). As a result of these concerns it was agreed with the RAEng that a sample of SME firms should be included. A further six interviews were therefore undertaken during November and December 2005. Details are given in Table 2. For reasons of access all were conducted over the telephone. Other aspects of data collection were as already outlined for the earlier interviews. For clarity and focus in this report the results are discussed separately in Part Four.

Company	Sector
Cadogan Consultants	Engineering services
Cold Drawn Products	Manufacturing (metals)
Cultech Limited	Research and manufacturing (food)
Grimley Smith Associates	Engineering services
Lightweight Medical Limited	Engineering services
Technical Support Associates	Engineering services

Table 2- Expert Interviews - SME Participant Companies

3.3 Extending the Sample – Spin-outs

In order to get a broader picture of engineering graduate requirements it was decided to obtain the views of university spin-outs. It was felt that the close working relationships such businesses have with universities and the embryonic nature of the business would influence the skills required of graduates in these organisations. Additionally, the high-growth potential of such businesses might have an impact on the types of engineering graduates being recruited. Seven interviews were conducted with key informants involved in spin-outs that had emerged from four UK universities to exploit their in-house intellectual property. The academic institutions were Brunel University, University of Cambridge, Imperial College, and the University of Oxford. The industries being assisted by the engineering technologies being exploited by the spin-outs ranged from oil and gas field development to computing. The size of business ranged from one individual (a recently incorporated spin-out) to over 100 personnel (a spin-out of about 10 years). The names of the companies have not been included for reasons of commercial confidentiality, given the differing states of maturity of the organisations concerned. The same interview schedule that had been used for the earlier interviews was adopted. However, because of the small size of many of the spin-outs and the relative immaturity of the businesses, a more flexible approach was taken to the use of the schedule. Six of the interviews were in some considerable depth ranging in time from over 30 minutes to 90 minutes. There was one brief interview of 15 minutes. Practical considerations dictated the duration of interviews and that all of the interviews be conducted over the telephone. Six of the participants agreed to be recorded. Recordings were transcribed generating almost 100 pages of material for analysis. Again the ATLAS.ti software program and the coding structure developed for the original expert interviews were used to analyse the transcripts.

3.4 The Focus Groups

Although the overall logic of the research design was around the use of expert key-informants with extensive experience, the decision was taken to include a small sample of recent graduates to understand their views on the subject of skills. It was felt that the inclusion of this stakeholder group would add both to the richness of the picture of graduate skills, as well as a potentially different understanding of the issues and possible solutions.

3.4.1 Sample Details

Three focus groups, drawn from recent graduates enrolled on the RAEng Executive Engineers Programme, were carried out in October 2005. Each focus group was based on a cohort of the programme, with the cohort loosely reflecting the number of years since graduation. Twenty-eight graduates were involved. The breakdown of cohorts and number of participants in each group is shown in Table 3 below:

Cohort Number	Main Graduation Year	Number of participants
1	2004	11
2	2003	10
3	2002	7

Table 3- Cohort Participant Data

Participants came from a wide range of industries including construction, oil and petrochemicals, aerospace, consultancy and manufacturing. Each focus group also included a wide range of engineering degrees, covering a number of core disciplines including mechanical, civil, electronic, electrical, and chemical. Within the groups there were graduates from Bath, Birmingham, Bradford, Bristol, Cambridge, City (London), Durham, Exeter, Imperial College (London), Leeds, Nottingham, Newcastle, Oxford, Queens (Belfast), Sheffield, and Strathclyde.

3.4.2 Data Collection – Focus Groups

A series of questions was developed based on the findings emerging from the in-depth interviews. The purpose of the questions was to stimulate discussion and to collect specific information about the range of skills used by graduates in their current roles; how well university prepared them for work in industry; how well university helped them to develop the skills required; what their view was on the balance between theory and practice in their courses and how universities could improve the balance if required; and finally what skills they expected to need in the future and how they would go about acquiring such skills.

Each focus group was asked the same set of questions and all members of each group were encouraged to participate in the discussions. For certain topics (current skills requirements, future skills requirements and how future skills might be obtained), group members were also asked to record their initial thoughts in writing, prior to sharing and discussing those within the group. This 'nominal group technique' approach (Van de Ven and Delbecq, 1974) was used to maximise initial variety of ideas, whilst still benefiting from subsequent group discussion. In addition, it allowed participants' written responses to be collected after the session to support analysis. Each focus group was audio recorded, with the permission of the participants, and current and future skills requirements captured on flipcharts for later analysis. The focus group sessions lasted about 75 minutes each and were run in parallel. A full focus group schedule is provided in Appendix 2. As noted above, the written responses to certain questions were also used in the analysis.

3.4.3 Data analysis – Focus groups

As far as was practically possible, the focus group recordings were transcribed. The transcriptions were analysed by hand using a broad, high-level coding structure, with the primary unit of analysis being the whole group. Additional analysis was supported by ATLAS.ti. Where written responses were collected, contributions of individual participants could also be analysed. Material from the completed questionnaires was collated into an Excel spreadsheet. Current and future skills were reconciled against the flipcharts used during the sessions. All the material from the questionnaires, including information which identified how the respondent was going to develop future skills, was analysed to identify common themes and patterns.

3.5 Phase Two – The Survey

Having described the primarily qualitative elements of Phase One, the remainder of this chapter focuses on the quantitative survey that was the core of the Phase Two research effort. Note that whilst some details of analysis are included here, reference is also made to specific techniques during discussion of the findings.

3.5.1 Instrumentation

The questionnaire was developed especially for this research. It consisted of eight sections as shown in Table 4. Most of the questions were close-ended, but some open-ended questions were included. A copy of the questionnaire is included at Appendix 3. The questionnaire was pre-tested by members of the Henley faculty with engineering industry experience. The questionnaire itself was prepared using the TeleForm data capture programme. In addition to the paper-based version, an online version was also created. The questions in this were identical, having also been generated using TeleForm. The online questionnaire was hosted on the Henley Management College website.

Section	Topic	Number of Questions
I	Current graduate recruitment direct from university	3
II	The quality of UK engineering graduates*	5
III	The quality of engineering graduates from overseas**	2
IV	Engineering graduate recruitment and development	6
V	Recruitment of recent graduates §	3
VI	A Scenario for the future	8
VII	Future skills needs of engineering graduates	5
VIII	About you and your organisation	9

* Throughout, the term 'engineering graduate' was used to refer to those holding Bachelors or Masters degrees in engineering; the term UK graduate (unless otherwise noted) referred to graduates of UK universities

** This section referred to engineering graduates from overseas universities

§ This section referred to the recruiting of engineering graduates with 1-2 years engineering experience rather than directly from unversity

Table 4 - Questionnaire Structure

3.5.2 Sampling

The questionnaire was administered by Findlay Direct Marketing during December 2005. The target population to which the survey was administered was manufacturing, research and development, design and engineering consultancy organisations with twenty or more employees across the whole of the UK. The employee headcount limiter was chosen on the basis that very small firms were unlikely to be significant recruiters of graduates. The questionnaire was sent by post with a covering letter from the RAEng and a pre-paid reply envelope to 8,247 contacts in organisations within the sampling frame[1] . In addition, the covering letter contained details of a hyperlink to a web-based version of the survey for those who preferred to submit electronically.

3.5.3 Data Collection

A total of 444 useable responses were received to the Phase Two questionnaire, a response rate of approximately 5.4%[2]. Of those responses, 24 were submitted electronically via the Web-based interface. The remaining 420 were paper-based replies returned by post. These were scanned into a database using TeleForm. Manual entry was also used for open-ended responses to specific questions.

3.5.4 Characteristics of the Sample

Just under two-thirds of the sample were independent UK companies or subsidiaries of UK companies, whilst 35% were subsidiaries of non-UK companies. Within the sample dataset, manufacturing firms predominated, accounting for 56% of responses. The next largest contributor was engineering services which made up 15%. Transport firms contributed 5.3%, whilst all other sectors were below 5%. There were respondents from throughout the UK, with South-East England being the best represented (23%). Scotland, Wales and Northern Ireland combined represented about 11% of the respondents[3]. Looking at the size of organisations responding, just under half the firms reported turnover in excess of £50 million; 6% had turnover below £2 million. In terms of number of employees, just over 47% had more than 250 full-time equivalents, whilst smaller firms (50 or below) made up 21% of the sample. For nearly two-thirds of the firms in the

[1] The possibility of duplicate responses from organisations is recognised. Checks suggest, however, that this is unlikely to significantly influence the findings.

[2] In addition, 11 questionnaires were returned that were either blank or the respondent declined to complete the survey.

[3] As an indication of the significance of this figure, according to the National Audit Office 12.6% of VAT registered UK production firms are located outside of England.

sample, engineering graduates made up 10% or less of total employees; in only 10% of cases did they constitute more than half. Finally, respondents were also asked their own job titles. Some 45% located themselves within the engineering/ technical/R&D category. Fourteen percent described themselves as at the level of general manager or above. It is difficult, of course, to be certain of the representativeness of this sample. Whilst larger firms are over-represented, it is clear from the survey data returned that they are more active recruiters of graduates than smaller firms, since many small firms recruit graduates only occasionally (and some not at all) . From the point of view of understanding the industry perspective on engineering graduates the sample can therefore be thought of as adequate. This is reinforced by the relative homogeneity in response on key topics such as graduate quality (discussed in detail in the findings).

3.5.5 Data Analysis

Analysis was primarily carried out using SPSS 12.0 for Windows, a widely used statistical analysis package. Since much of the dataset was categorical, extensive use was made of non-parametric tests such as Chi-squared tests of association, but multivariate statistical techniques including factor analysis, cluster analysis, and conjoint analysis were also employed (for an overview of these methods see Hair et al., 1998). Attention is drawn to such applications in the discussion of the findings. Where appropriate results of significance tests are also noted in the findings. In addition to the use of SPSS, analysis of the open-ended responses was carried out using WordStat 4.0, a specialist Content Analysis software program.

3.6 Combining Qualitative and Quantitative Methods

This research can be thought of as mixed-method in the sense of combining both qualitative and quantitative methods (Tashakkori and Teddlie, 1998). Whilst the qualitative interviews provided important input to the survey design, the broad approach has been one of methodological triangulation where the two methods have been used to develop a fuller understanding of the phenomenon under investigation than would have been possible had the research relied on only one method. Thus, in the presentation of the findings, data from both sources are used.

Part Three: The Engineering Graduate Today

Part Three begins the presentation of the research findings by looking at the engineering graduate of today. It begins with an overview of the roles that engineering graduates are expected to fill and the skills that are required by those graduates if they are to perform those roles effectively. It then reviews evidence regarding the quality of UK engineering graduates, including a comparison with graduates from overseas universities. Part Three concludes with a look at the topics from a different perspective, namely that of recent engineering graduates as revealed in the focus groups.

4. The Engineering Graduate in Today's Industry

This chapter develops a picture of today's engineering graduate as revealed by both the interview respondents and the survey. After a short review of the pattern of graduate recruitment indicated by the survey, the chapter sets the scene in terms of the roles firms want engineering graduates to fill. It then considers the skills and attributes that they look for in the graduates they recruit. The chapter concludes with a look at some of the strategies used to find, recruit, and develop engineering graduates with the required skills. Both survey and interview data are used to give a 'thick' description of the topic.

4.1 The Pattern of Graduate Recruitment

Sixty percent (n = 259) of the survey respondents reported recruiting engineering graduates directly from university. Whether or not firms recruited in this way was associated with a number of demographic variables. These included ownership structure[4], as shown in Table 5, which suggests that independent UK companies are rather less likely to recruit graduates directly than subsidiaries of either UK or non-UK companies. In addition, organisations with a higher proportion of engineering graduates on their staff and larger organisations appear more likely to recruit graduates direct from university[5]. There is also evidence of an association between industry sector and direct recruitment but the importance of this is difficult to ascertain since this seems partly to be due to the impact of manufacturing companies which also tend to have a lower proportion of graduates in their workforce.

Organisation's ownership structure						
Does your organisation recruit graduates direct from UK universities?		**Independent UK Company**	**Subsidiary of UK Company**	**Subsidiary of non-UK Company**	**None of the above**	**Total**
	Yes	52.1%	63.3%	68.9%	54.2%	59.7%
	No	47.9%	36.7%	31.1%	45.8%	40.3%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5 - Direct Recruitment and Organisation's Ownership Structure (% Responding)

There was also considerable variation in the number of graduates recruited. Whilst one quarter recruited more than five graduates annually, nearly half (49%) recruited two or fewer per year (Figure 2). Not surprisingly there was a strong relationship between firm size and graduate recruitment. Nearly all of the firms taking more than 20 graduates annually had more than 500 employees whilst at the other end of the spectrum, over half of the firms with 50 or fewer employees recruited fewer than one graduate per year.

[4] Significant at the 5% level

[5] Significant at the 1% level

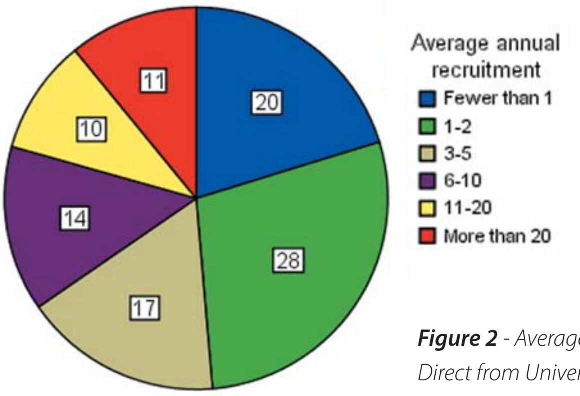

Figure 2 *- Average Annual Recruitment of Engineering Graduates Direct from University (n= 259) – % Reporting*

4.2 What Engineering Graduates Do

There is no simple way of categorising what engineering graduates actually do, as was apparent from the language used by interviewees when discussing the roles of engineering graduates. Some respondents spoke in terms of disciplinary expertise, such as chemical, mechanical, or software engineering, although this was often associated with discussion of specific domains of technical expertise rather than the broader academic disciplines. Moreover, as the following comment from a senior manager in the construction sector illustrates, organisations employ an increasing number of disciplines: 'when I joined [the company] there was one discipline, which was called structural engineering…. When I checked two years ago with HR I don't know how many disciplines we recognised, it was about seventy-six. Over the years the range of things that we do has broadened'. One implication of this is that industry sector may be a relatively poor indicator of the type of engineering graduate actually being recruited by individual engineering companies. This was confirmed by the survey data. For example, whilst manufacturing firms that took graduates direct from university looked to recruit primarily mechanical, production/manufacturing, and electrical engineers, they also recruited systems engineers, computer scientists, and chemical engineers. A very small number of manufacturing firms even recruited civil and building services engineers. Similarly, electrical/electronic engineers were looked for by all of the sectors covered in the survey.

In general, however, discussion of engineering graduate roles in the interviews emphasised the very broad range of job activities in which individual graduates would be employed rather than particular engineering disciplines. The survey therefore included a series of questions to explore this area. The first asked respondents in what roles graduates would be used in their first two years after recruitment. The results are shown in Figure 3 where design and research and development predominate. Interestingly, only 5% of respondents reported using graduates in line management roles, although graduates were likely to find themselves involved in project management, and it seems likely that there will be some managerial responsibility in other roles.

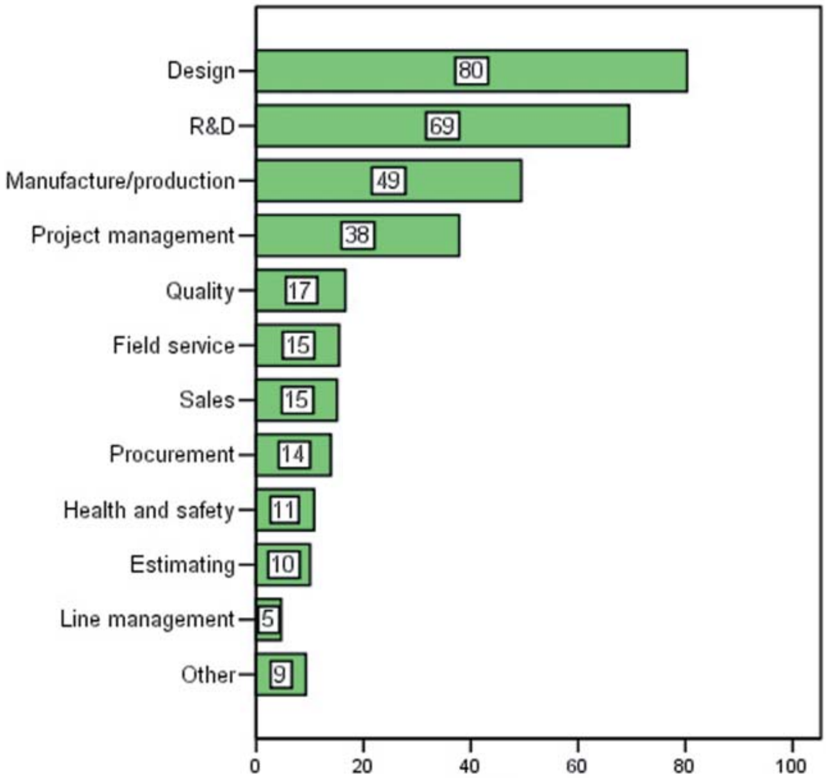

Figure 3 *- Graduate Roles within Two Years of Recruitment (n = 259)*

From an analysis of the data, three key themes emerge regarding graduate roles. Firstly, depending on the sector, engineering graduates were to be found in a wide variety of operational roles. This is evident from Figure 3 with such activities as field service and quality, and is nicely illustrated by the following quote from an interviewee: 'I could have somebody who is a shift supervisor, I could have somebody who is a reliability engineer, I could have somebody who is an operational support person… looking after maintenance plans, operational plans for an individual installation and servicing them…. I've also got people on the engineering side, whether we're replacing equipment or we're re-engineering a process'.

Secondly, as is clear from Figure 3, engineering graduates are used across all phases of the product lifecycle and throughout the value chain, from research and development through to sales and marketing. Whilst research and development and design clearly dominate, 15% of firms reported using engineering graduates in sales roles. 'You can't sell these products without understanding them, and the sales process involves a very close relationship with the customer, understanding their requirements, making sure the solution is correct… even sales and marketing are highly engineering-focused' was how one executive described the need for engineering know-how in sales. Interestingly, the survey data suggest that whilst there is no significant association between industry sector and the use of engineering graduates in sales roles, there is a strong link between firm size[6] and such use. The data suggest that larger firms are much more likely to deploy newly-recruited engineering graduates in sales roles.

A third theme, which emerged primarily from the interview data, was the importance of engineering graduates as integrators, able to provide solutions to customer problems. Typically, this was discussed in the language of systems engineering. This was how one respondent described this perspective: 'I should think probably half our business would fall under a systems engineering heading in a broad sense. That is, looking at understanding customers needs in terms of large syndicated systems, making sure that those are properly designed and configured so we can actually deliver the end result'. The end result might well include products from other firms, as well as products from elsewhere in the organisation.

[6] As measured by staff numbers; significant at the 1% level.

The data thus show not only the range of roles in which graduate engineers might find themselves, but also the extent to which those roles might diverge from hands-on discipline-specific engineering. One outcome of this is that, in the opinion of one interviewee, 'remarkably few engineering graduates are actually practicing what would be remotely recognisable as what they were being taught, or even connected with it'. As well as having implications for education and training, this has implications for the expectations of those joining engineering firms. In the words of one respondent: 'there's this perception amongst the graduate population that engineering is engineering. If you're in electrical engineering then you're going to join an electrical engineering company, you expect to do electrical engineering. Wake up and smell the roses, it might not be the case'. This situation was seen as both a potential problem because of a possible mismatch between the expectations of new recruits and the reality of their job roles, and a potential opportunity in terms of the breadth of career opportunities available to engineers. As another interviewee described the situation 'I think for some of them [graduates] it's a bit of a shock, because they expected us to be engaged in slightly more specialist engineering, than we are…. On the other hand, to some people it can also be quite liberating because they find that there's a lot of other interesting things that engineers get involved in, quite apart from pure engineering'.

4.3 The Skills and Attributes Expected of Engineering Graduates

What skills and attributes does industry currently demand of the engineering graduates it recruits to fill these diverse roles? One response to this question comes from a manager in the manufacturing sector: 'we're typically looking for people with a quality degree from, ideally, a quality university, but also we're looking for all the behavioural competencies that are so difficult to find; like team player, good communicator, with a business focus'. From a different sector comes this statement of requirement for engineering graduates: 'we clearly want them very good technically but we want them to have this wider ability to work in a team and also try to encourage them to get a wider view of the world outside their immediate areas; more rounded individuals'. These quotations also suggest that a potentially useful way of discussing skills requirements is to distinguish between technical and other skill sets. Further evidence for this comes from the survey where respondents were asked to rate their satisfaction with graduate skill levels in seven different areas (the detailed results for these questions are presented in the next chapter). The responses were analysed using a multivariate statistical technique known as factor analysis, which looks to define a set of common underlying dimensions, called factors, within a larger set of variables (in this case the seven different skill areas). The resulting analysis[7] generated two factors, summarised in Table 6, which suggests that the survey participants distinguish between these two broad sets of skill. These sets have been labelled 'defining' skills and 'enabling' skills. The word 'defining' has been chosen to suggest that this set of skills, which are primarily related to the technical domain, actually define what is unique about an engineer. The 'enabling' skills, on the other hand, are those that enable effective performance in a social domain such as an organisation but which are not necessarily unique to engineers. Each domain will now be explored, drawing on the findings of the in-depth interviews.

Factor 1: Defining Skills Technical Domain	**Factor 2: Enabling Skills Social Domain**
Theoretical understanding	Communication
Practical application	Team-working
Technical breadth	Business skills
Creativity and innovation	

Table 6 - Skill Factors

4.3.1 Defining Skills: the Technical Domain

There appeared to be general, if not always explicit, agreement amongst interviewees that technical skill is the core requirement for an engineering graduate: 'first and foremost technical skills' as one respondent put it. Whilst what constitutes the specific body of technical knowledge is very much discipline-specific, there seemed to be a

[7] The specific technique used was principal component analysis, with varimax rotation. Total variance explained was 57.2%.

commonality in terms of how a technical skill was perceived that crossed engineering disciplines. One senior manager explained it in terms of graduates understanding 'how something works… the fundamental principles underpinning its design and operation'. For many interviewees a key to this was a solid grounding in the fundamentals of a particular discipline along with the mathematics of engineering. 'A big dispute in the engineering profession has been the importance of mathematics and therefore we can all have different opinions', observed one executive, 'but I am convinced we do need our engineering graduates to be fluent in mathematics too'. In specific cases, knowledge of physics was also seen as a core component of technical competence. The importance of these two subjects was underlined by companies recruiting physics and mathematics graduates, rather than just engineering graduates, into engineering-related roles.

Another reason for stressing fundamentals was because they were seen to provide a foundation for the mastery of technological change. At the same time, however, there was clearly a need for graduates to be familiar with the latest developments, even if some of those (e.g. specific software tools) might soon be obsolete. One interviewee described this problem in terms of "transient" knowledge, and the fundamentals which were "sustaining" knowledge. 'There's a very interesting combination of getting that mix of permanent knowledge and the transient knowledge. Without the transient they [graduates] can't be effective on day one and therefore won't be employed, but in ten years' time... that transient knowledge will be irrelevant to them'.

Another tension that emerged from the interviews was the challenge of balancing breadth and depth in engineering knowledge. Whilst much of this was around technical versus non-technical skill sets, there was also recognition that this challenge played out within the technical domain as well. For most interviewees, narrow technical specialists were increasingly a thing of the past. 'We do have our fair share of boffins who work only by themselves' explained one director, 'but they're rare now and more of a dying breed. The eccentric that has a particular skill is still around but not many of them'. A potential benefit of in-depth knowledge even after the specific domain had become obsolete was that it demonstrated, as one respondent put it, an 'ability to master something difficult'. In most cases, however, the ideal engineering graduate combined depth and breadth. Based on previous experience, this is one interviewee's description of the 'model' engineering project manager: 'they needed to be highly competent in at least one technical skill, they needed to be fluent in the fundamental principles of engineering design, they needed to be able to stand and actually be amongst the best in their field, but they needed an understanding of the other engineering and technical disciplines that went into the project'. This links back to the already mentioned point about the role of graduates as integrators with the ability to think in systems terms.

Another important requirement, identified by several interviewees, is the application of theory to practice. This perspective is summed up nicely in the following extract: 'we have a bunch of people whose intelligence we've tested but… I'm not interested in the intelligence per se, I'm interested in the ability to do something. The ability to make a difference, the ability to innovate, the ability to create something. And I wonder how many engineering graduates you could put out there and say manufacture something, design something for me?'. Creative problem solving was also seen as important by a number of respondents. According to one interviewee this required more than addressing simple problems but instead the ability to 'take a high level problem and run with it'. Another interviewee described the sort of qualities required: 'I'm also looking for the drive and energy to challenge the thinking, the current thinking, and look for solutions. With that, further drive to go and make those solutions happen.' Within the current research, the concept of creativity and innovation is intended to capture this important attribute.

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4.3.2 Enabling Skills: the Social Domain

The second broad category encompasses the enabling skills that facilitate effective performance. An important sub-group here is a range of inter-personal skills. This is how one respondent outlined the key dimensions of this sub-group: 'they are around communication, they are around ability to work with people and they're around the way in which people think'. Ability to communicate was a key selection criterion. 'Another thing we absolutely look for is a good user interface' explained one interviewee, 'so looks good, smells good'. Communication was seen as important in every engineering role today, indeed another interviewee suggested that inability to communicate was a real career-limiting factor. Participants tended to link communications skills to the ability to work with others. Again this was an important part of the selection process for several respondents: 'when we're at interview and assessment we're usually looking a lot at personality factors and what we're looking for is people that will be directionally more outgoing and therefore be good team players and ultimately, later on, good managers of people'. One reason for this was the ubiquity of the team as a basis for work organisation within the companies studied. The growing need to work closely with customers, suppliers and other partners was also an important driver behind the emphasis on personal skills. As one interviewee noted, 'business is about communicating and doing work with other people, whether it's externally or internally within the company, and having good strong interpersonal skills is a massive factor'.

A second sub-group of enabling skills encompasses business and commercial competencies. There was general agreement that commercial awareness was a central skill needed by engineers. One senior executive, however, suggested that it was not so much a skill as an 'attitude - consumer awareness, openness to consumers; consumers are always right. Engineers tend to be the last people in any business enterprise to realise that. They think they've been equipped with some divine insight into what the product should be, and the customer must therefore be educated rather than listened to'. What did not appear to be required or expected was that new graduates would have specific business skills beyond this general commercial sensitivity. Indeed this was one area which most companies expected to address as part of their own training programmes. In the words of one manager: 'I'm not hugely bothered about business skills. I think as long as they have common sense they will learn the business skills pretty quickly when they come on board'. The main exception to this was project management, but even here most interviewees only expected graduates to have a basic understanding. Safety issues were also mentioned by some respondents. Overall then, business skills were seen as important but not something that engineering graduates were expected to have mastered prior to being recruited. More important was the potential to develop, and that included developing appropriate management skills.

4.4 Finding and Developing Engineering Talent

The final part of this chapter takes a brief look at the processes and practices used by firms to recruit and develop their graduate engineering talent. The aim of this is to highlight the extent of commercial business involvement in the skill formation of engineering graduates. To this end, questions were included in both the interviews and the survey to understand how organisations recruited and developed new engineering graduates.

4.4.1 Graduate Recruitment Practices

Starting with the recruitment process, Figure 4 summarises the recruitment methods used by those organisations in the survey that recruited graduates directly from university. Most companies used more than one, with nearly 80% reporting that they used three or more of the methods identified. There was a significant relationship[8] between the number of methods reported and the size of the firm, with larger firms being more likely to use a range of recruitment practices. There was no evidence, however, of a significant industry effect. Examining the available data in more detail, three broad models of recruitment become evident. The first model involves the 'traditional' recruitment routes. Most obvious here is general advertising, which 68% of respondent firms reported using. Interestingly, one interviewee reported that posting vacancies online had led to an increase in applications from overseas even though there was no active targeting of non-UK universities. Activities such as recruiting through careers fairs, including the traditional 'milk round' at universities, can be also placed into this category. Predictably, careers fairs tended to be used by the larger companies in the survey. Of importance too is the use of recruitment agencies, which 42% of firms reported doing. The data suggested that it was the mid-sized firms that were most likely to use agencies.

[8] Significant at the 1% level.

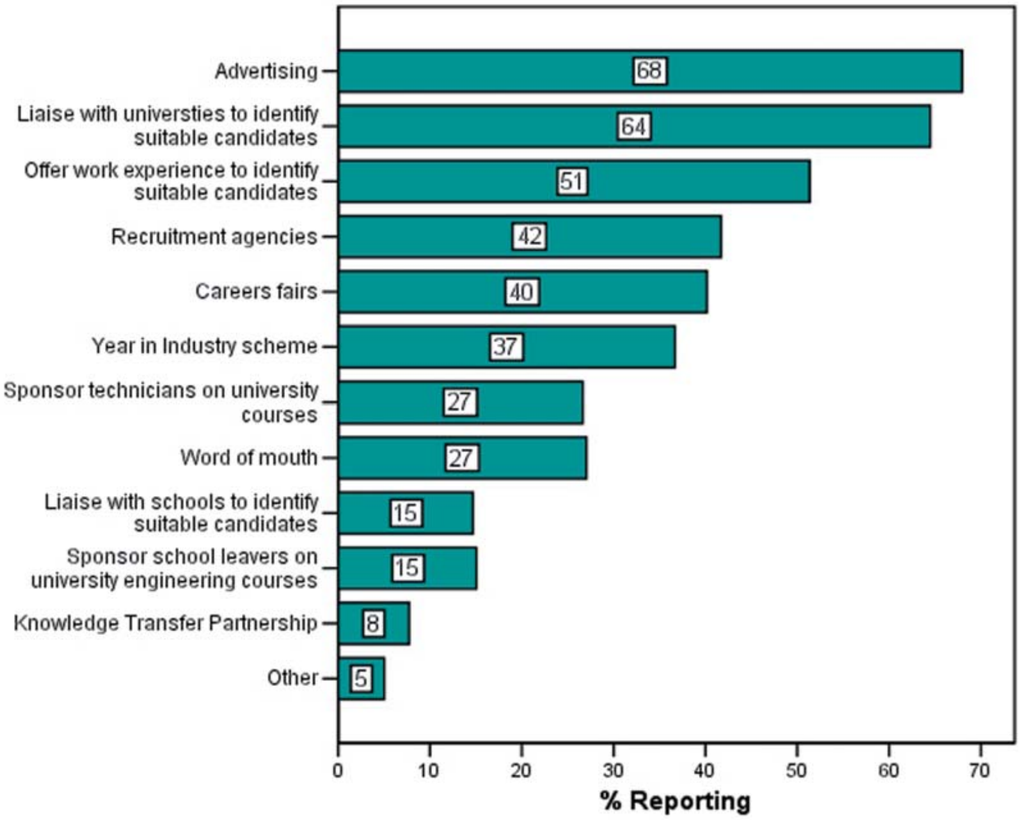

Figure 4 *- Recruitment Methods Used (% Reporting, n = 259)*

A second general recruitment strategy involves collaboration with educational institutions to identify potential candidates prior to graduation. Liaison with universities is the most important (reported by 64% of organisations recruiting graduates direct from university), but some firms are also involved in much earlier targeting of potential employees by liasing with schools. The survey data suggest, however, that it is larger firms that are more likely to use this strategy. There was also a suggestion from the interviews that some companies were increasingly active in the latter, working more closely with schools both directly for recruiting for their own needs, and more generally to enthuse youngsters and encourage them to take up engineering.

A third general approach to recruiting is via work experience programmes. The importance of this is underlined in Figure 4 which shows 51% of firms using it as a recruitment method. Also important (37% of respondent firms) is the Year in Industry scheme. In terms of actual practice, the interviews showed a range of methods used. In some cases firms offered summer placements or other work experience to university students, sometimes combined with sandwich courses. Alternatively firms reported identifying potential candidates as part of the Year in Industry or other work experience programmes prior to university. This could involve an element of sponsorship through some stage of the university programme, although the survey data suggest that this is not a widespread practice (15% of firms reporting). Again, these recruitment methods were more likely to be used by larger firms.

4.4.2 Work Experience and Recruitment Prospects

Figure 4 highlights the importance of work experience placements in the recruitment process, something also evident in the interview data. Such placements were seen by interviewees as offering benefits to both parties. They gave potential applicants an opportunity to see the company and experience its work at first hand and they gave the company the chance to evaluate a potential recruit much more closely than would be possible using more traditional recruitment practices, such as interviewing. Consequently a series of questions was included in the survey to assess the attractiveness of work experience to recruiters. The results are presented in Table 7 which confirms that a candidate with engineering-related work experience is more likely to be recruited than an otherwise comparable candidate lacking such experience. It is interesting to note that non-engineering work experience or 'gap' year experience is not particularly attractive to those surveyed.

Type of Experience	No difference		More likely to recruit		Significantly more likely to recruit	
	n	%	n	%	n	%
Year in Industry scheme	27	11.3%	138	57.5%	75	31.3%
Engineering work experience prior to university	34	14.0%	148	61.2%	60	24.8%
Engineering degree sandwich course during vacations	39	16.3%	133	55.6%	67	28.0%
Engineering work experience	21	8.4%	181	72.4%	48	19.2%
Non-engineering work experience	179	80.6%	42	18.9%	1	0.5%
Gap year prior to or after attending university	190	82.6%	31	13.5%	9	3.9%

Table 7 - Impact of Work Experience on Likelihood to Recruit Compared to Equivalent Candidate without Work Experience

4.4.3 Bachelors or Masters?

It is useful to draw attention to the fact that the research revealed no clear message regarding whether employers preferred to recruit engineering graduates at Masters or Bachelors degree level. A survey question was used to ascertain what level of engineering degree, Bachelors or Masters, was looked for by respondent companies. Just under half expressed no preference, 21% of respondents recruited primarily Masters, and 23% recruited primarily Bachelors. Five per cent recruited exclusively Masters-level graduates. There is evidence, however, to suggest that preference for level of degree is related to both industry sector and firm size[9]. The data indicate that, compared to manufacturing firms, engineering service firms are somewhat more likely to prefer Masters-level graduates[10]. Also, large firms (more than 500 employees) are more likely than medium-sized firms (51-250 employees) to prefer Masters-level graduates[11]. Further analysis was conducted to see whether firms reporting that they used graduates in research and development and design roles preferred Masters-level graduates, but this proved to be not the case.

This somewhat equivocal position was echoed in the interviews. Looking at the problem from the point of view of the individual student, one interviewee suggested that a Masters-level qualification was becoming a differentiator for engineering graduates: 'the straight Bachelors engineers are going to be struggling to compete because they're not differentiated'. A contrasting view questioned the cost-benefit pay-off for a Masters student compared to someone with a Bachelors degree: 'if you compare the difference in salaries between the two, it is not anywhere near comparable with the amount of extra fees that somebody has to pay to do that one extra year. It's something like ten years that they'd have to be working to actually recoup… and generally by then, you've found they've equalised anyway'.

4.4.4 Graduate Training and Development

Data were also gathered on the training and development programmes that firms offered newly-recruited engineering graduates. The results are summarised in Figure 5. Whilst 43% of respondents indicated that they had a formal company graduate training programme, several other approaches were used. Of interest is the frequency of formal

[9] One-way ANOVA significant at the 5% level.

[10] Bonferroni post hoc test significant at the 10% level.

[11] Bonferroni post hoc test significant at the 5% level.

mentoring schemes for new graduates (38% of respondents), something which the interviews also highlighted. Overall, 70% of respondent organisations reported having one or more training and development schemes in place, although it was large firms (more than 500 employees) that were more likely to have more than one such scheme[12]. Looking more closely at those reporting that their organisations had no formal training scheme (30%), there was a significant association[13] between firm size and lack of formal training scheme. Fifty percent of companies with fifty employees or fewer had no such scheme, compared to 11% of companies with 500 or more employees. There was also an indication of difference by industry sector, with manufacturing companies being more likely to have no formal scheme than other sectors..

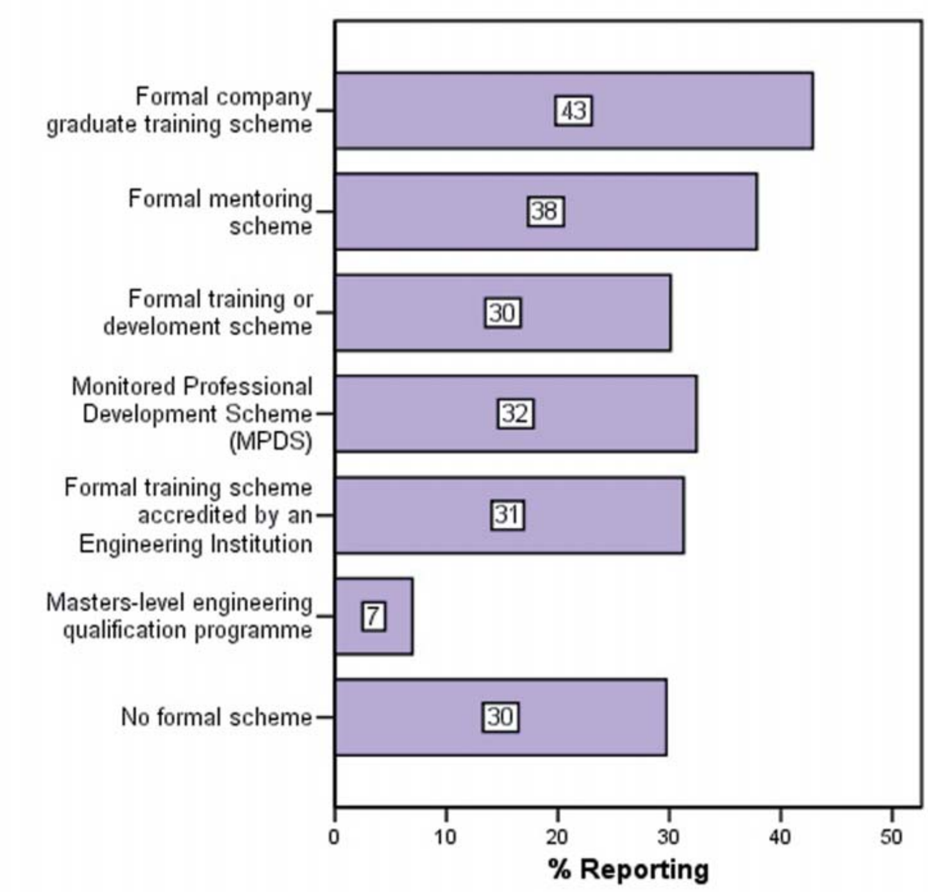

Figure 5 *– Training and Development Schemes (% Reporting)*

The interview data offer additional detail on company practices as far as training and development are concerned. Selection and induction methods appeared to be fairly standardised across the larger companies. Most respondents reported using multiple interviews, often supplemented by team work and practical exercises, along with psychometric testing in some cases. Typically, successful candidates would then attend some form of induction programme designed to give them an overview of the business and meet their peers, including non-engineers. In most cases, newly arrived graduates could expect to join a company graduate training programme, typically of two years' duration. There was considerable variation between companies but most of them included business and management and personal skills components along with a technical element, linked in many cases to professional development as part of the acquisition of chartered status. Some firms had a policy of rotating graduates through different job roles although this was not universal. In addition, several companies offered mentoring schemes to their new graduates. One dimension in which schemes varied was the extent of centralisation, with some evidence that this might be increasing. Another difference between companies was the extent to which the patterns of career development were left up to the individual.

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[12] One-way ANOVA significant at the 1% level.

[13] Significant at the 1% level.

4.4.5 Chartered Status

Although several firms offered support for the acquisition of Chartered status, the in-depth interviews revealed no clear agreement on its importance. In some cases it was seen as a valuable career development vehicle, in others a matter for individuals but one which offered little or no commercial benefit to the organisation. Survey respondents were therefore asked how important Chartered status was to their organisations. On a scale of 1-5, where 5 was very important, the returned mean was 3.28, suggesting that it is of some importance to the organisations in this dataset[14]. In terms of demographics, the importance of Chartered status was significantly related[15] to firm size, industry sector, and organisational structure. The larger the firm, the more likely Chartered status is to be important. Breakdown by sector is shown in Table 8.

Sector	n	Mean	Standard Deviation
Utilities	8	4.3	0.71
Construction	5	4.2	0.84
Engineering services	39	3.9	1.10
Manufacturing	102	3.2	1.31
Telecommunications	8	2.5	0.93
Transport	15	2.5	1.36
Other	44	3.2	1.19
All	221	3.3	1.28

Table 8 – Importance of Chartered Status (1 = very unimportant; 5 = very important)

4.5 Other Recruitment Patterns

The processes discussed above apply to 'traditional' graduate entry routes, direct from UK universities. The research showed, however, other routes by which firms recruited engineering graduates.

4.5.1 Technician Graduates

The first of these emerged during the interviews which revealed a few cases of technicians who had gone on to university, sometimes with company sponsorship. One company made particular use of this approach, valuing the enthusiasm and practical flair shown by such individuals. Another interviewee commented on the practical and operational skills of technician graduates. Figure 4 shows 69 survey respondents (27%) indicating that their organisations sponsor technicians on university courses. From the data it appears to be larger companies that are more likely to offer such sponsorships[16]. Whilst outside the remit of the current research, there is clearly scope for further investigation of this area.

4.5.2 Post-experience Recruitment

A second approach emerged during the interviews with SMEs (reported in Part Four). Those interviews showed that some firms looked to recruit graduates only after they had some industry work experience, rather than recruiting them directly from university. This research uses the term post-experience recruitment to describe such graduates who are recruited after 1-2 years of working in industry[17]. Accordingly a set of questions was included in the survey to capture data on such recruitment. In all, 278 firms (64% of all respondents) indicated that they hired graduates once they had one or two years work experience. This high figure suggests that this is an important practice for the firms surveyed. The data are analysed more fully in Part Four.

[14] Result significant at the 1% level against a test value of 3.

[15] Result significant at the 1% level using One-way ANOVA.

[16] Chi-squared test of association significant at the 5% level.

[17] This time limit was designed to distinguish such recent graduates from 'experience hires'.

4.5.3 Graduates from Overseas Universities

A third way firms obtain graduates is by recruiting from overseas universities . The survey showed that nearly a quarter of respondent organisations that recruited graduates direct from UK universities also recruited graduates from overseas universities. Further analysis, including discussion of the quality of such graduates, is contained in the next chapter.

4.6 Summary

The key points emerging from this chapter can be summarised as follows:

- Engineering graduates are used across the product lifecycle and throughout the value chain, and many engineers are likely to find themselves in roles which do not necessarily involve hands-on specialist engineering. As a result, an increasingly important role for many graduate engineers is as an integrator, with a systems-thinking perspective.

- Firms look for skills and attributes in two broad areas:

    - Defining skills, which encompass the domain of technical skills, including a sound knowledge of the engineering fundamentals within their discipline, built on a solid basis of mathematical know-how. There is still a requirement for narrow specialists but for many engineers breadth of technical awareness is more important, provided it is based on the fundamentals already mentioned. The ability to apply theory to practice is also highly sought-after.

    - Enabling skills, the domain of the social and interpersonal skills and attributes that allow the engineer to operate effectively in team-based working environments. These include communication skills, team-working skills and business skills. For entry-level graduates, business skills primarily involve awareness of the commercial implications of engineering decisions rather than detailed, specific education in business and management.

- A range of methods is used to recruit and develop graduate engineers into large engineering firms. Whilst advertising is the most widely used method, many companies work closely with universities to identify suitable candidates, and work placements play an important role in the recruitment process. In terms of skills development, whilst nearly one-third of companies have no formal scheme in place, 70% of firms do offer some form of formal graduate development programme.

5. How Good are UK Engineering Graduates?

This chapter looks at the evidence regarding the current quality of engineering graduates from UK universities. It begins by looking at particular skill shortages and skill gaps before going on to consider how UK engineering graduates compare with their counterparts from overseas universities. This is followed by a short summary of how respondents perceive engineering graduate quality overall, before concluding with a discussion of the reported impact of skill shortages.

5.1 Skill Supply

A starting point for examining the quality of UK engineering graduates is to review the supply of graduates and whether their skills meet industry needs. This discussion will be structured around the problem of skill shortages, where there is a lack of appropriately qualified graduates available to be recruited, and skill gaps, where there are particular deficiencies in the skills of graduates that are available.

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[18] It should be noted that the focus here is not on the country of origin of the graduate but on the location of the university at which they studied.

[19] In this context the term 'UK engineering graduates' is used to refer to graduates of engineering courses at UK universities.

5.1.1 Skill Shortages

Skill shortages were measured indirectly by asking whether organisations found particular types of engineering graduate difficult to recruit. The results are summarised in Table 9. Building services, systems engineering, civil, and electrical/electronic appear to be the most problematic areas for recruitment. Other problem areas mentioned by respondents included aerospace/aeronautical engineering (n = 6), metallurgy (n = 4), and materials science (n = 3). There was little evidence for any significant association between firm size and difficulty of recruiting, except for mechanical engineers where firms with 51-250 staff were more likely to report recruiting problems.

Type of Engineer	Number of firms recruiting	Not a problem to recruit		Difficult to recruit	
		Count	%	Count	%
Building services	14	4	28.6%	10	71.4%
Systems engineering	99	39	39.4%	60	60.6%
Civil	25	10	40.0%	15	60.0%
Electrical/electronic	169	70	41.4%	99	58.6%
Production/manufacturing	119	60	50.4%	59	49.6%
Chemical	34	19	55.9%	15	44.1%
Mechanical	209	120	57.4%	89	42.6%
Computer sciences/software	109	63	57.8%	46	42.2%

Table 9 - Recruitment Difficulties (% Reporting)

A rather similar picture emerged from the interview data which identified specific areas in which there were skill shortages at graduate level. Three respondents complained of a shortage of manufacturing engineers, although in one case the problem was more one of retention than recruitment. There were also concerns about the supply of electrical engineers, with particular deficiencies in this area being seen as design of electronics and knowledge of analogue electronics. In the latter case it appeared to be more an issue of course content, with digital electronics supplanting analogue, rather than just a shortage of electrical engineers per se. Similarly, another respondent noted a lack of heavy power engineering graduates, attributing this to the focus on IT and electronics. Within the construction sector, building services engineers and civil engineers were mentioned as being in short supply. In the case of civil engineering at least this shortage was felt to be industry wide, the problem being, as one respondent put it, 'an image thing'.

Image, of course, is a long-standing topic for debate within engineering and one which also featured in the research. It is not intended to rehearse that debate here, but it is worth noting that image at the level of the industry, the sector and the firm were all seen as important in getting bright youngsters onto engineering courses at university and recruiting and retaining good graduates within specific firms.

5.1.2 Skill Gaps

The term skill gap traditionally refers to the extent to which current workforce skills fall short of the standard required. Since this particular study concentrates on the early years of a graduate engineer's career, including recruitment and induction, the term will be used rather more loosely to cover skill deficiencies in those graduates who are, on paper at any rate, qualified and available to fill a particular post rather than just forming the current workforce. To get an indication of skills gaps, respondents were asked to report their satisfaction with seven broad sets of skills and attributes that had been identified as important in the Phase One research. The results are reported in Table 10 where satisfaction with seven skill sets are rated on a 1-5 scale (5 = very satisfied). Weaknesses are suggested in terms of practical application, business skills, and technical breadth, whilst strong points are team-working and theoretical understanding. There is little evidence for any large difference in response by demographic factors, such as firm size. It is worth noting, however, that whilst these strengths and weaknesses are statistically significant they may not vary significantly from a practical point of view. In other words, Table 10 can be read as suggesting that overall industry is neither satisfied nor dissatisfied with the skills of engineering graduates across these seven dimensions.

Skill Set	Skill and Attribute	n	Mean	Std. Deviation
Defining skills	Theoretical understanding	255	3.32**	0.950
	Creativity and innovation	255	3.08	0.893
	Technical breadth	255	2.89*	0.873
	Practical application	255	2.70**	0.934
Enabling skills	Team-working	252	3.40**	0.830
	Communications	255	3.06	0.863
	Business skills	256	2.71**	0.794

** = significant at 1% level   * = significant at 5% level

Table 10 - Satisfaction with the Skills of Graduate Engineers (1 = very dissatisfied, 5 = very satisfied) [20]

On the whole, therefore, there is no real evidence of wholesale skill gaps as far as the companies in the sample were concerned. A number of areas were highlighted, however, and these are discussed below. To maintain consistency with the review of skill needs in the previous chapter, this discussion of skills gaps will be grouped around the set of defining skills and the set of enabling skills.

5.1.3 Defining Skills

Starting with defining skills, an interesting contrast emerges between the interview and the survey data. Table 10 suggests a positive view of graduates' theoretical understanding whilst a number of interviewees in fact expressed concerns about the extent to which graduate engineers have the fundamentals of engineering principles. 'I think a lot of them [new graduates] struggle on the basis that they don't have a solid technical foundation fundamentally in the first place'; 'they've learnt how to answer questions, they're bright enough to do that. But they haven't learnt the principles', were typical comments. Even more apparent was concern over mathematical skills, a concern that several interviewees traced back to what they saw as the deficiency in mathematics teaching in schools. One senior executive summed it up as follows: 'there are some basic mathematical capabilities issues. I think the maths teaching is not what it was, or it is, but our demand exceeds our capacity. So our demand to churn out people with maths skills exceeds our capacity to teach them. And I'm not just talking about university, I'm talking about schools'.

Both sets of data do agree, however, in showing concerns about practical application. The interviews help flesh out the numbers in Table 10. 'The one failing of universities now' commented one interviewee 'is that some of that theory never gets translated into reality'. An extreme example was given by one firm which had experience of electrical engineering graduates 'not being able to read a schematic, or identify basic components… quite often they have not seen surface mount components'. However, some interviewees noted that certain courses were better than others in terms of practical content. Work placement schemes were also seen as a great opportunity for students to gain valuable practical experience.

5.1.4 Enabling Skills

As far as the set of enabling skills and attributes is concerned the picture is again rather mixed. Whilst Table 10 suggests that there is no strongly negative perception of communication skills and that team-working skills are viewed rather positively, interview participants certainly had some concerns in this area. 'I think many of our engineers are technically very good. I think many of their people skills are underdeveloped' is how one senior manager perceived the problem. Communications, team-working, and general interpersonal skills were mentioned by various interviewees as weaknesses in graduates they had encountered. The reason for this apparent discrepancy may lie in the fact that in practice weaker candidates tend to be weeded out through the recruitment process. 'We just don't hire people who aren't good enough' one interviewee pointed out

[20] The significance test results reported here are one-sample t-tests against a test value of 3, this being the 'neutral' mid-point of the 5-point scales used in each case. A statistically significant result therefore indicates a significant deviation from a neutral stance, implying that, on average, respondents feel negatively or positively towards the topic concerned.

In terms of business skills, the general perception emerging from both sets of data appears to be that they are in most cases not well developed. On the other hand, as pointed out in the previous chapter, firms may not expect any high level knowledge of such areas from new graduates so there is no obvious consensus on whether this is a serious issue. In broader terms, however, lack of awareness about what engineering firms actually do, and thus what graduates in those firms would be required to do, was a concern for some interview participants. 'We don't want to have a mismatch between the expectations of the graduates who are being developed in universities and then the actual practical roles they're going to be dropped into' warned one interviewee. Another concern was that engineering graduates were insufficiently 'organisationally-savvy' and this could limit their career potential.

5.1.5 Qualified on Paper

In connection with graduate quality, one of the interesting issues that emerged from the interviews was the perception that paper qualifications were not a guarantor of appropriate skill levels. This was commented on by a number of interview participants, and to some extent confirmed by the extensive efforts in assessment as part of the recruitment processes used by most firms. There was also a feeling amongst some interviewees that it had become increasingly difficult to rely on class of degree as an indicator of quality since it was felt that there had been considerable inflation of grades in recent years. As one interviewee put it 'almost everyone's getting a 2:1…, which makes it very difficult for us to differentiate, who really are the top engineers… because so many of them are getting a 2:1 and a First'. Talking of past experience with graduate recruitment, one manager expressed frustration with this situation in the following terms: 'you're interviewing people that you're struggling to see how on earth they could match with the piece of paper that you have in front of you'. There was also doubt about the consistency of university engineering courses, especially in the newer universities. 'You've got the Russell Group which are generally pretty good but then once you drop out of the Russell Group then the quality seems to drop out as well' was how one respondent expressed this concern. 'It's so frustrating not to be able to get a consistent level out of the graduates, and know what you're going to get' complained another.

A further complication in this context may have arisen as a result of modularisation of engineering courses. One aspect of this, as already pointed out in the discussion of skill shortages in electrical engineering, is the perceived difficulty of relating paper qualification to actual course content. Whilst one explanation could be lack of agreement as to what is important within a specific discipline, another explanation is that some topics are seen by students to be more difficult than others. Noting, for example, that analogue electronics was often perceived as a harder subject than digital electronics, one interviewee suggested that this encouraged students to opt for the latter. The result was that 'issues can arise within the modular structure of people picking things that are perceived to be easier to get a higher-quality degree [in]…. So you could end up with a degree in Electrical Engineering with very little analogue electronics, nothing on antennas and such like. Gone are the days when it was said that unless you did that you didn't have the breadth of subjects'. It is possible that this view accounts for the lower satisfaction with graduates' technical breadth shown in Table 10.

5.2 Graduates from Overseas Universities

As well as the quality of engineering graduates from UK universities, the research also set out to investigate the perceived quality of engineers from non-UK universities. Before reviewing those findings, it is useful to consider the reasons given by interviewees for recruiting overseas graduates. In a few cases individual engineers were recruited explicitly in response to supply-side factors, including obtaining hard-to-recruit specialists. Thus one company reported looking to Poland to fill specific skills vacancies for which there was a perceived shortage of suitable UK graduates. In other cases, firms were clearly responding to demand-side pressures and opportunities, for example recruiting foreign nationals for their local knowledge in order to support overseas expansion or as part of overseas operations. A third factor was that for multi-national companies such as some of those within the research sample, the 'war for talent' had become as global as their product marketplaces. (Another aspect of overseas recruitment was linked in particular to offshoring and this will be discussed later in the report).

Space precluded very detailed examination of this topic within the survey, but two questions were included. In response to the first question, 69 organisations reported that they recruited engineering graduates from overseas universities. The data indicate that there is an association[21] between an organisation's ownership structure and recruitment from overseas universities, with subsidiaries of overseas firms being most likely to recruit such graduates and subsidiaries of UK companies being the least likely. Larger firms, as measured by staff size, also recruit more engineers from overseas universities. The second question in the survey asked for those respondents' general view on whether such graduates were better than their UK counterparts. On a scale of 1 to 5, with 5 being 'graduates from overseas universities significantly better', the returned mean was 3.58, indicating that respondents perceived the quality of graduates from overseas universities to be somewhat higher[22].

The in-depth interviews offer some additional insights into the quality of graduates from overseas universities. A number of interviewees felt that graduates from Continental Europe were particularly competitive. German and French engineering graduates were seen as having very good mathematical and theoretical knowledge, whilst the tendency for longer courses in those countries meant more opportunity for practical experience as well. As far as engineers from the United States were concerned, the perception was more one of parity, although one respondent argued for the superior interpersonal skills of US graduates, at least those from the best US universities. Japanese engineering graduates were also felt to be of a very high standard. One interviewee in particular suggested that Japanese engineers exhibited a superior understanding of inductive, empirical problem-solving. Of course, given current debates over offshoring, the quality of engineers from China and India is of particular interest. Interviewees suggested that the quality of the best engineering graduates from both countries was extremely high, even if the overall standard was perhaps lower than the UK. This was seen to matter less from the Chinese point of view because of the very large numbers of graduates being produced each year. As one manager observed 'the problem we've got in China - we don't understand the scale, we can't grasp the scale'.

In reflecting on the above analysis it is especially important to recognise the limitations of the data, not the least of which, as some interviewees noted, was the tendency to have encountered only the best of graduates from overseas universities, rather than a representative cross section of all such graduates. In addition, only a relatively small number of companies in the survey actually recruited graduates from overseas universities. Based on the data available, however, it is probably fair to conclude that the best UK engineering graduates are currently broadly comparable to their overseas counterparts, whilst recognising that the best graduates from universities in some overseas countries may have strengths in certain areas.

5.3 The Quality of UK Graduates

How good, then, are UK engineering graduates overall? This chapter began with a review of issues in the supply of skills before looking at the output of overseas universities. This section now provides a general overview of the question as perceived by industry, along with some broader comments on the state of UK graduate engineering, as revealed by the research.

5.3.1 Quality and Quantity

Within the questionnaire used in the survey, respondents were asked on a scale of 1-5 (1= very dissatisfied, 5 = very satisfied) how satisfied their organisation was overall with its ability to recruit engineering graduates of suitable quality from UK universities. The mean response was 3.00 indicating that overall respondents were neither satisfied nor dissatisfied. There was no significant difference between the demographic groups identified within the survey, which suggests a reasonably consistent industry-wide view on the question. A richer picture is offered by the interview data. Some respondents were in fact very positive in this respect. 'I have to say the standard is very good' said one senior manager, adding: 'I am very impressed, despite all the rumour stories about shortages of engineers, we have no problem recruiting engineers'. Perhaps more typical, however, would be those whose experience was of a rather tighter labour market, requiring careful selection but in which they were nevertheless able to recruit the people they needed.

[21] Result significant at the 5% level.

[22] Result significant at the 1% level.

According to one interviewee, 'in the UK generally, if we're very, very careful about the selection, we can just about get what we want'. The tight labour market was also reflected in the cost of getting good people. 'We can still get them' explained another interviewee 'they're getting expensive, and we have to pay a lot more for them. But, yes, you can still get them if you're prepared to pay the price'. Other companies, however, painted a more negative picture in terms of the quantity of suitable graduates available. In the words of one respondent 'I think they actually meet our skills requirements pretty well. We get some exceedingly good graduates out of UK universities, we just don't get enough of them'. Another interviewee was even more critical 'we need a good number of the best [graduates] and it is getting impossible to get the right number of those people'. The overall impression from the data is that most companies appeared to be able to find the quality of engineering graduates that they needed from UK universities, albeit within a somewhat tight labour market.

5.3.2 Broader Issues

At one level these findings could be taken as indicating that the supply of engineering graduates from UK universities poses no serious issues for the industry. In order to investigate this further, the survey included two questions to judge how firms were affected by any skills deficiencies that they were experiencing.

5.3.3 The Impact of Skills Deficiencies

The first question asked respondents to report the impact on their organisation of any problems that they were experiencing in recruiting engineering graduates of suitable quality from UK universities. The aggregate results are summarised in Figure 6. The figures suggest that skill deficiencies impact a broad range of activities. Most frequently reported (39%) is increased recruiting costs and this helps put into perspective the opportunity costs that are implicit in the extensive recruitment activities described in the previous chapter. Note also that more than one third of respondents indicated that skill deficiencies impacted on new product development and business growth. Finally, it is also useful to emphasise that only 9% of respondents reported that such deficiencies had no significant impact.

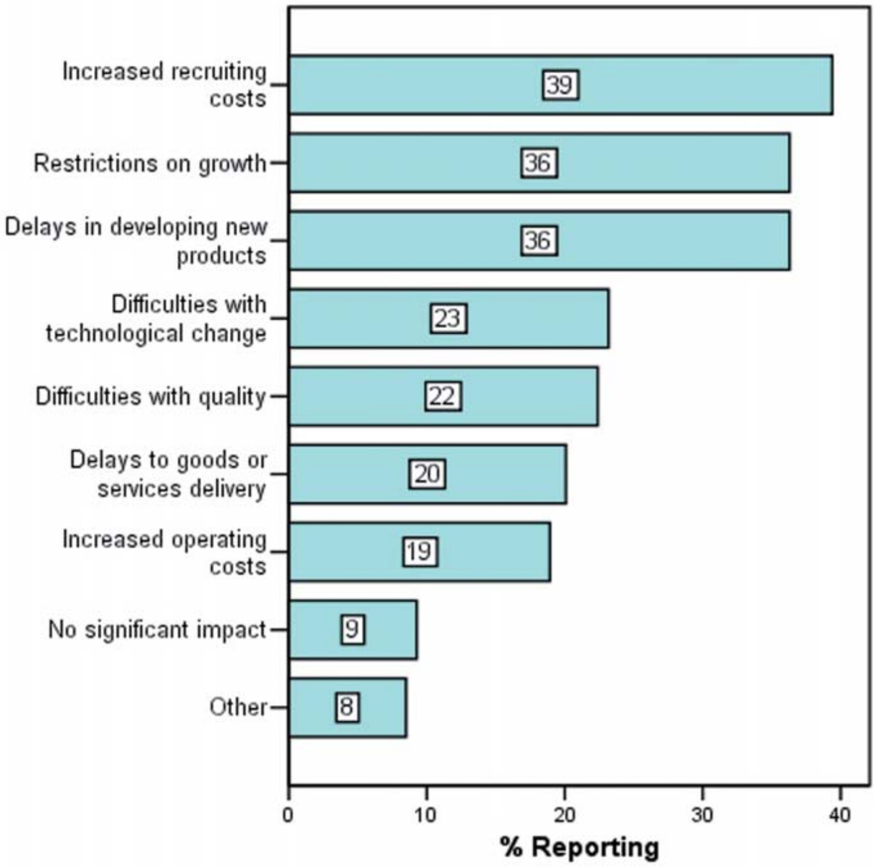

Figure 6 *- Impact of Skill Deficiencies (% Reporting, n = 259)*

A second survey question asked respondents to identify actions being taken in response to any problems recruiting suitable engineers. The findings are summarised in Figure 7 and the strategies employed can usefully be subdivided into three general groups. The first involves what might be thought of as an 'upskilling' approach. It includes increasing training either of existing staff (42%) or newly-recruited graduates (35%), and/or by using non-graduates in graduate roles (28%). The second strategy involves an 'outskilling' approach, involving either the use of agency engineers (34%) or outsourcing. Survey firms reported outsourcing to both UK-based third parties (23%) and offshore third parties (12%). Additionally, 14% reported relocating work to offshore subsidiaries in response to a lack of skilled graduates. The third strategy could be described as 'inskilling', since it suggests attempts to acquire suitably skilled graduates in the face of shortages. This included intensifying recruitment activities (reported by 37%), increasing salaries (21%) and recruiting from overseas universities (20%). Taken together, Figure 6 and Figure 7 suggest that the impact of perceived skill deficiencies amongst UK engineering graduates is not trivial.

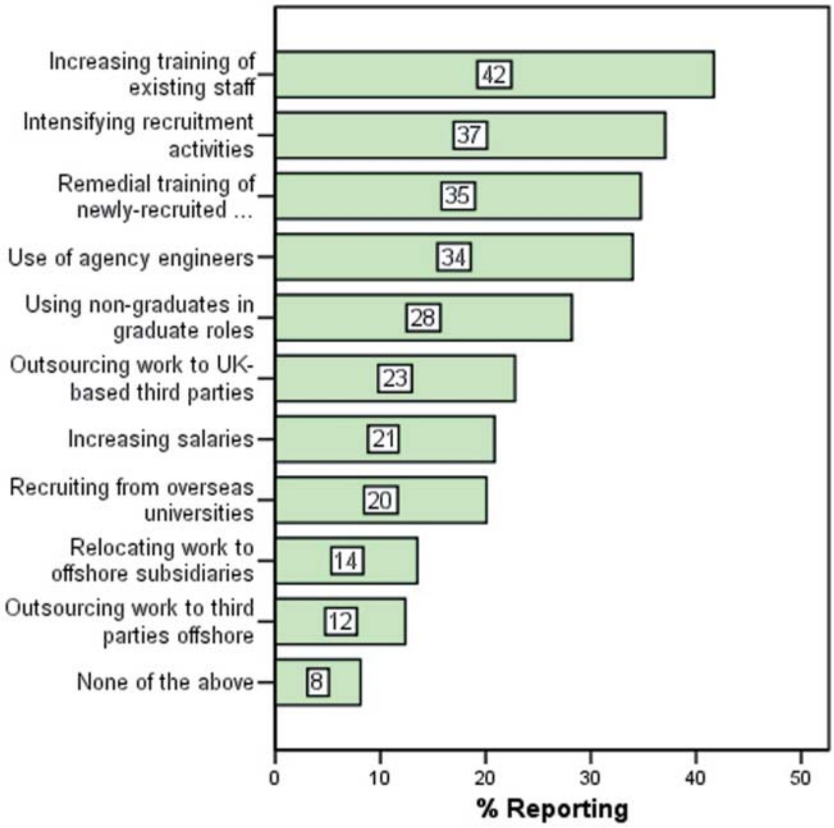

Figure 7 *- Actions Taken in Response to Skill Deficiencies (% reporting, n = 259)*

5.3.4 The Future Supply of Engineers

In addition to the issues noted above, the research also reveals concern amongst some interviewees about the 'pipeline' of future engineering graduates. One aspect of this is the problem of mathematics teaching which has already been mentioned. Other worries were around the image of the industry and its ability to attract talented youngsters from school onto engineering courses and into the industry. As one interviewee saw it 'rather than beating up the universities for failing to inculcate certain skills, I prefer to beat up the universities for not attracting in the right people. It starts in the schools, getting the right engagement'. In this connection there was a feeling that students were disinclined to take on what were seen as difficult subjects like engineering, physics and mathematics. 'Many courses in engineering are perceived as being hard, in the time that's required, and boring' commented one respondent, adding that 'if you want people to go and be engineers you've got to make it a bloody sight more fun'.

5.4 Summary

The key messages from this chapter can be summarised as follows:

- Overall, respondent firms appear generally to be able to get appropriately skilled engineering graduates from UK universities, with some caveats regarding the quantity available, which suggests a tight labour market for high quality engineering graduates.

- There is some evidence of skill shortages (where there is a lack of appropriately qualified graduates available to be recruited) and skill gaps (where there are particular deficiencies in the skills of those graduates that are available) in the UK graduate engineering labour market. There is a feeling that the grade of degree awarded is often a poor indicator of a candidate's actual abilities.

- The research suggests that firms recruit engineering graduates from overseas universities both as a response to specific skill shortages and in order to support their overseas operations. In terms of quality, the best graduates of UK universities are probably broadly comparable to graduates from overseas universities.

- More broadly, concerns are raised in three areas not immediately obvious from the research data:
    - Firms report that skills deficiencies impact across a range of activities, including increasing recruitment costs, delaying the development of new products, and restricting firm growth. In addition, the elaborate recruitment and skills development programmes adopted by firms can be seen as coping strategies in a tight labour market, which represent an opportunity cost to the industry.

    - Actions taken by firms in response to perceived skill deficiencies include 'upskilling' by increasing training, 'inskilling' through intensified recruitment efforts, and 'outskilling' through the use of third parties, including those overseas.

    - Long-term, there is doubt over the pipeline of young talent into engineering from schools, onto university engineering courses, and subsequently into engineering firms.

6. The Graduate Perspective

In order to round out the view of graduate engineering it was felt important to talk to recent graduates about their own experiences. This chapter therefore presents the findings of the focus group research carried out in Cambridge in October 2005 and is structured along the lines of the focus group framework used on the day.

6.1 Why Go into Engineering?

Participants were firstly asked about what it was that prompted them to choose an engineering degree. As might be expected, there was a wide range of responses but some key themes emerged. Firstly, it was considered that engineering provided a good all-round degree which enabled the graduate to keep their career path options open – it provided the opportunity to 'change at any point – banking, more scientific roles, you can still change at a later time.' Secondly, there was a strong sense of wanting to make a difference, of contributing to society which culminated in something visible where the engineer could say 'I did that' and that it was 'great to see what you have designed and built.' Thirdly, there was the creative element, where engineering was seen as a creative subject with a strong practical dimension. The influence of parents was also important – several focus group members had parents who were pursuing engineering careers. Some had also seen engineering as an opportunity to get a degree with the help of sponsorship thereby minimising the level of debt on graduation.

6.2 The Skills Engineers Need

This section reviews current and anticipated skills needs for engineers.

6.2.1 Current Skills

Analysis of the responses to the question concerning the five most important skills required in their current job role created a list of some fifty different skills. Selecting those with two or more responses from each cohort produced a shorter list of six as shown in Table 11 below:

Skill		% of cohort	
	Cohort 1	Cohort 2	Cohort 3
Communications	82%	90%	71%
Creativity and Innovation	45%	30%	29%
Technical ability	56%	40%	57%
Problem solving	36%	20%	14%
Analytical skills	27%	10%	14%
People management	36%	60%	29%

Table 11 - Assessment of skills requirements for current engineering role (percent of each cohort indicating what skills are required in current role (multiple responses possible))

Table 11 shows that communication skills were considered important by the largest proportion of each cohort population. Communication skills encompass both verbal, written, and presentation communications and are very much in line with the findings of the expert interviewees in that employers expect graduates to have good communication skills. A clear second in the list is technical ability which includes understanding technical issues and problems and having a continuing desire to expand technical knowledge and horizons. Next is creativity and innovation skills with people management coming a significant fourth.

Not surprisingly when asked which of these six skills was considered to be the most important, the overwhelming response was communication. Communication was seen to link in with other people-based skills such as managing people, leadership, team working and influencing skills, as well as a means of sharing lessons learned. The fact that recent graduates consider that they need these skills early in their engineering careers would suggest that such skills need to be nurtured and developed whilst carrying out their academic studies at university.

6.3 University Experiences

When the focus groups were asked, based on their own personal experience, how well they thought their university engineering courses helped to develop these skills, the comments were varied. Some thought that students should be developing such skills anyway as part of their 'growing up' process, whilst others felt that university should be providing the foundations on which to build later on. Others commented that the degree to which the skills were developed was dependent upon the desire of university staff to foster such skills. It was also suggested that some universities provided elements of project management methodology that give the graduates concerned a head start in their new 'real life' engineering role. Having strong links to university business schools was also seen as advantageous for engineering departments in helping to develop business-oriented skills.

The overall impression gained was that there were no major problems but that participants certainly felt that there were areas for improvement. For example, project work was seen as important in developing a variety of skills such as communication and the practical application of theory. In many cases, however, the amount of project work was limited and often lacked a context or sense of reality. 'It's a whole different ball game when you go out into the real world' was how one participant summed up the problem. Another respondent explained this lack of realism in the following terms: 'every project we did at university was essentially around solving a problem; we never once talked about how that problem came about, the direction we were expected to go in and what the real factors in the solution should be'. So whilst project work was universally seen as important, it was felt that it often needed more relevance and realism. Another criticism was that assessment often placed too much emphasis on rote learning and memory whereas, as one participant argued 'actually in industry, you're not left there going "oh! what can I remember…?" a lot of the time it is, "How do you know where all the stuff is in a book…?" Just because you can't remember 100 equations doesn't mean you're not going to be a good engineer'. A further criticism was the lack of reference to external design standards and codes of practice during the course. This could lead the employer to criticise graduates about their lack of awareness of legal and regulatory requirements for the design of plant and equipment.

6.3.1 Developing Skills at University

The focus groups were also asked for examples of activities included in university courses which had helped them to develop the skills they needed. The most common response, notwithstanding the caveat noted above, centred around the use of project work. 'I think university has done a pretty good job for me, in terms of equipping me with some of those skills' explained one participant, 'I think the main way that they did that was through the group projects…. In terms of planning, time management, working with people , communication, leadership you can get a lot of stuff from that in the artificial university project'. Others noted the lack of opportunity for practical experience. 'We hardly did any hands on at all' observed one recent graduate, 'and I really noticed that being in this job for nearly four weeks now I've already been out on site a couple of times and can actually see first hand what's going on and what's going to be obstructing other people. I definitely don't think we had enough experience practically.' Some participants also suggested that extra-curricular activities, such as team sports, were useful in developing softer skills.

6.4 Future Skills Needs

Focus group members were also asked to reflect on the skills they expected to have to develop for their future careers. The results were quite varied, reflecting perhaps the greater divergence in expected job roles. However, several common themes emerged, again across all three cohorts, as illustrated in Table 12 below. It is interesting to note that communication skills were not seen as a skill they would need to develop further in the future. This could be interpreted as reinforcing the importance of communication as a current skill, and one which becomes fundamental and underlying to the engineering graduate – a skill which is taken for granted. There are three other points of interest in Table 12. The first is that technical ability seems to increase in importance the further away from graduation an engineer gets. This could be down to a realisation by graduates that university has not taught them everything and that technical ability is also based on practical experience – a realisation which will grow over time. The second point of interest is the high percentage in each cohort that consider people management skills to be important – 60% and above. Some focus group members specifically mentioned team working and leadership. For the purpose of this analysis, these two skills, which are significant in their own right, have been incorporated under the heading of people management because of their close association with managing people. The third point of interest is the significance attached to financial management by the middle cohort.

Skill		**% of cohort**	
	Cohort 1	**Cohort 2**	**Cohort 3**
Communications	18%	0	0
Creativity and Innovation	9%	10%	14%
Technical ability	9%	20%	43%
Problem solving	0	0	0
Analytical skills	0	0	0
People management	64%	60%	86%
Business management	0	0	29%
Financial management	0	80%	14%

Table 12 - Assessment of future skills requirements (percent of each cohort indicating what skills will be required in future role (multiple responses possible))

Members of the focus groups were also asked to identify how they would go about acquiring these additional skills. The modes of acquisition included formal training courses, self-study, practical experience and exposure, and increasing levels of responsibility. For most individuals a mixture of all these approaches was identified.

6.5 The Balance between Theory and Practice

As the analysis of the industry expert interview transcripts progressed, it became apparent that one concern for engineering industry employers was the balance in engineering courses between theory and its practical application. The focus groups were therefore given the opportunity to explore this issue and share their experiences. The general

impression was that most courses leaned towards the theoretical rather than practical. Indeed several participants reported having very little practical work at all in their courses. 'Very, very little opportunity to do practical' commented one participant, 'there was one project in the second year, we got a bit of time in the workshop, but other than that pretty much didn't have any other opportunity to do any at all'. It also emerged that the practical elements of courses could sometimes be skewed to the beginning of the course rather than spread evenly throughout.
Some participants suggested that the lack of practical application might be down to budgetary constraints, in the case, for example, of projects not being taken beyond design stage. It was also suggested that university lecturers were often hired for their research capability and their ability to generate income for the university, with teaching seen as almost secondary to this. It is, however, important to note that practice was not seen as an alternative to theory. 'What I wouldn't like to see in engineering courses', warned one participant, 'is taking the basic technical engineering training away from those courses. The basics are so important and you might not remember it, but you know where to look.'

6.6 Summary

The key issues in this chapter can be summarised as follows:

- Communications, technical ability, creativity and innovation, and people management are seen as key skills at this point in the graduate's engineering career. However there is some debate over the role of university in developing such skills.

- Experiences at university were generally positive, but with concerns from some participants about lack of relevant project work and emphasis on rote learning and memory.

- Participants held similar views to the industry expert interviewees regarding the amount of practical application included in engineering courses.

Part Four: Different Perspectives

Part Four continues to look at the current engineering graduate but this time from the particular perspective of two groups of firms within the engineering industry, namely SMEs and start-ups. Whilst the analysis so far has not excluded such firms, it was felt important to look more specifically at their requirements and to highlight the research findings in these areas. The first chapter in this section therefore takes a look at the views of small- and medium-sized engineering companies to see whether their experiences differ, and if so in what ways, from the general picture painted so far. The second chapter looks at another interesting constituency within the industry, namely start-up businesses, as represented by spin-outs from universities.

7. The SME Perspective

This chapter picks up on some of the themes covered in the previous three chapters but from the perspective of the representatives of SME engineering companies. Its inclusion is a reflection of the concerns summed up in the following comment from a senior executive in a major manufacturing company: 'if I look at the ability [of our company] to hire engineers of world-class quality in the UK, actually we can still do it. What worries me is that, if I role up the whole of the manufacturing industry in the UK, which includes all our suppliers and all the people we depend on, there's a problem: we can't get enough high quality engineering graduates'. It seemed likely that smaller companies, with fewer resources and consequently unable to employ the diverse recruitment strategies described earlier, might find recruiting more difficult. In any case, it was inevitable that the pool from which they are drawing will contain many of those candidates rejected by larger companies as unsuitable. As a result, additional in-depth interviews were undertaken, targeted specifically at SMEs, and a number of questions added to the survey to reflect what were felt might be particular issues for such firms. This chapter draws attention to areas of similarity and difference in the needs and experiences of engineering SMEs. It begins with a review of the findings of the in-depth interviews, before analysing the survey data to test some working hypotheses.

7.1 What Are SMEs Looking For?

At one level, SMEs appeared to be looking for engineering graduates to display a skill set that was remarkably similar to that already described. Technical engineering competence and appropriate personal skills and attributes were seen as fundamental requirements. One respondent summed this up when describing the company's selection criteria as involving 'basically two things. One, their portfolio of work – what sort of standard it is, what they did at university, where we can see there's been some sort of good engineering work done, whether it is realistic, and whether they were innovative at all – and the second aspect is really down to personality – how we think they'll get on with the team, if they're going to be proactive, if they're going to be hardworking, enthusiastic about what they're doing'. Business knowledge was less important, again the implication was that new graduates could only be expected to have an awareness. 'I think it's difficult for universities to teach that sort of thing' suggested one interviewee 'and I think it's unrealistic of industry to expect graduates to have much experience of that'.

The most noticeable differences emerged in terms of recruitment and development practices. Obviously, smaller companies were recruiting far fewer graduates than larger firms, less than one per year in all cases studied. Recruitment tended to relate more directly to specific vacancies, although in some cases there did appear to be a concern to recruit young graduates to ensure there was a better age balance within the workforce. A range of recruitment techniques were reported, including the use of agencies and word of mouth. Prior knowledge of potential candidates, for example through work placement, was seen as helpful. There was also some evidence of a preference for recruiting from local universities. Given the small numbers involved, it was also not surprising that formal graduate training programmes were not in place. Instead, mentoring seemed a favoured way of supporting new recruits. The following comment by one manager is typical: 'there's no formal training as such but each person will be given a sort of mentor that will look after them for the first year…. To be honest everyone's sort of hands-on, because we're a small company, so they will be fully involved all the time in everything we do'. Interviewees also specifically mentioned providing support for acquisition of chartered status.

The ideas of 'full involvement' and 'hands-on' permeated the interviews. 'Another member of the team. To sort of get involved' was how an interviewee from an engineering services company described the expected role of a new graduate. Within the engineering services firms the general picture was one of graduate engineers who started off 'getting hands-on experience with the actual day-to-day stuff' before progressing on to project management roles. For the manufacturing companies, the situation was a little different with a much greater emphasis on prior experience. 'I would be very loath to take on a graduate who hadn't spent twelve months in industry' was one interviewee's comment. 'It would be very, very rare that we would take a direct university graduate without some industrial experience somewhere else….' observed another, adding that 'the opportunities that arise are real jobs, and we need real people who've got real experience to fill them'. What was being sought though was not what might be thought of as an 'experienced hire' but rather a graduate with a couple of years' industry experience. Whereas it appeared that engineering services had roles for direct entry graduates while they were learning the ropes, this did not seem to apply to SMEs in the manufacturing sector who looked for recruits who could be 'running as soon as their feet touch the floor'. In this connection a potential problem appeared to be whether the roles available in some SMEs met graduates' expectations. 'All graduates expect to be managers' suggested one interviewee, 'which I think in the long term is fine, if that's what they want to do, but I think that's not necessarily where they need to start, I think they need to start off hands-on'. 'We're not recruiting someone who is going to immediately take ten steps up the ladder and be in charge of a manufacturing division or something' said another.

7.2 Graduate Quality

The message on graduate quality from SMEs was mixed. About half the respondents were broadly happy; 'really good' was how one described current graduates. The biggest concerns were around the theme of practical application. 'I think often what's taught at university is extremely theoretical and it's not necessarily applied into a real situation' was how one interviewee put it. 'The thing I feel about graduates now, from my perspective, is they just don't get enough practical experience' was another comment. Quality of practical experience was also an issue. 'Over the last twelve months' explained one interviewee, 'I must have looked at three hundred CVs from students in a similar situation, and they've worked in McDonalds, and they've worked at bookshops and they've worked at Asda, and they've worked at Tesco… they can't get industrial training in a proper environment that would be ideal for a graduate student'.

The experiences of a company looking for graduates who already had some industry experience is worth quoting at length. 'For six months we've been trying to recruit for two [graduate engineer] positions, and basically our essential requirements have not been met…. For a start, there are less applicants out there who fit the engineering requirements. So ten years ago if you'd tried to recruit a certain type of individual you might have had twenty responses, now you'll get five responses…. And then of those that you do get to interview the quality of their previous experience and training is not the same level and quality that you would have got ten years ago'. Mechanical engineers were a particular problem. One possible cause was the reduction in the number of larger companies that had traditionally been a source of potential recruits. This tends to support the view that in manufacturing, at least, SMEs may be having more difficulty recruiting suitable candidates than larger companies. It also highlights the importance of understanding graduate skill formation from a broader perspective, in this case the interrelationship between SMEs and larger firms.

Respondents in this group also showed some concern about the consistency in the quality of degrees. 'I don't think in terms of research I can take on anyone confidently who has got less than a First Class Honours Degree, now', observed one interviewee, 'I mean that never happened ten years ago. I could take someone on with a 2:1, 2:2, and be fairly confident. They were not going to be brilliant, but they were going to be good scientists. Now, if I take on someone with a 2:1, I'm lucky if they're going to be competent'. Another respondent commented on the need to scrutinise what lay behind the actual degree awarded in much more detail than in the past.

A rather unexpected finding was that SMEs were being approached by overseas applicants for engineering positions. In fact the last three graduate engineers recruited by one company were all from overseas. Another interviewee commented on the high standard of presentation and qualifications evident in applications received from overseas.

7.3 Testing for Difference

The interviews therefore suggested a number of areas in which SMEs might differ from larger companies. These are most easily summarised in the form of working hypotheses which were formulated as follows:

H_1: SMEs are less likely to recruit engineering graduates direct from university than are larger firms.

H_2: SMEs are more likely to be dissatisfied with their ability to recruit suitable engineering graduates direct from UK universities than are larger firms.

H_3: SMEs are less likely to have formal training programmes in place for new graduates than are larger firms.

In addition, recognising the importance of recruiting graduates after some experience, two further hypotheses were proposed:

H_4: SMEs are more likely to recruit post-experience graduates than are larger firms.

H_5: SMEs are more likely to be dissatisfied with their ability to recruit suitable post-experience graduates than are larger firms.

It was already intended to collect data that would allow testing of the first three hypotheses and additional questions were included in the survey to accommodate hypotheses four and five.

7.3.1 SMEs and Direct Recruitment

The first three hypotheses relate to direct recruitment practices and this section reports the results of testing them. Table 13 shows that there is an association between the size of organisation, as measured by number of staff, and the likelihood of recruiting graduates direct from university. As can be seen, the data suggest that larger firms are much more likely to recruit in this way. H_1 is therefore supported: SMEs are less likely to recruit engineering graduates direct from university than are larger firms.

Question		Number of Staff			
		50 or fewer	**51 - 250**	**251 - 500**	**More than 500**
Does your organisation recruit graduates direct from UK universities?	Yes	32.2%	50.3%	66.7%	86.2%
	No	67.8%	49.7%	33.3%	13.8%
	Total	100%	100%	100%	100%
Chi-squared test of no-association significant at 1% level					

Table 13- Direct Recruitment by Firm Size (% Reporting)

H_2 (concerning overall recruitment satisfaction) was tested using one-way analysis of variance against responses to the question 'overall how satisfied is your organisation with its ability to recruit engineering graduates of suitable quality from UK universities?'. There was no evidence of a significant variation by firm size. H_2 is therefore rejected: SMEs are not more likely to be dissatisfied with their ability to recruit suitable engineering graduates direct from UK universities than are larger firms.

Looking at graduate training and development, the results of the test of H_3 are given in Table 14 which shows an association between firm size and reporting that no formal graduate training scheme was in place. The data suggest that larger firms are more likely to have such a scheme. H_3 is therefore supported: SMEs are less likely to have formal training programmes in place for new graduates than are larger firms.

Question		Number of Staff			
		50 or fewer	51 - 250	251 - 500	More than 500
No formal graduate training scheme	Yes	50.0%	50.0%	68.2%	89.3%
	No	50.0%	50.0%	31.8%	10.7%
	Total	100%	100%	100%	100%
Chi-squared test of no-association significant at 1% level					

Table 14 - Percent Reporting No Formal Training Scheme by Firm Size

7.3.2 SMEs and Post-Experience Recruitment

Reflecting that SMEs might prefer to recruit graduates only after they have had some industry experience, a set of questions was included in the survey to capture data on post-experience recruitment. In all, 278 firms (64%) indicated that they hired graduates once they had one or two years work experience[23]. This high figure suggests that this is an important practice for the firms surveyed. The recruitment experiences of these organisations is summarised in Table 15. The pattern is not dissimilar to that reported for direct recruitment, with the notable exception of chemical engineers where there appear to be more problems in recruiting graduates with some work experience.

Type of Engineer	Number recruiting	Not a problem to recruit		Difficult to recruit	
		Count	%	Count	%
Building services	15	5	33.3%	10	66.7%
Chemical	34	13	38.2%	21	61.8%
Civil	26	7	26.9%	19	73.1%
Computer sciences/software	124	66	53.2%	58	46.8%
Electrical/electronic	195	67	34.4%	128	65.6%
Mechanical	224	101	45.1%	123	54.9%
Production/manufacturing	132	64	48.5%	68	51.5%
Systems engineering	102	38	37.3%	64	62.7%

Table 15 - *Recruitment of Post-experience Engineering Graduates*

This set of questions also allowed testing of hypotheses four and five. Table 16 shows the results of an investigation of the relationship between recruitment of graduates, experience, and firm size. There is a clear association, significant at the 1% level, but the pattern is not exactly as predicted by H_4. Although the proportion of firms with 250 employees or below that recruit post-experience graduates is higher than that of similar firms recruiting directly from university, the highest proportion of firms recruiting post-experience graduates is actually in the 251-500 band. The largest firms do, however, appear to recruit fewer post-experience than direct-entry graduates. There is therefore only partial support for H_4. Further examination of the data did show that the proportion of the smallest firms (fewer than 50 staff) that reported recruiting post-experience graduates but not recruiting direct from universities was higher at 61% than for larger firms (13.5% for firms with more than 500 staff) which were more likely to use both recruitment methods.

[23] This time limit was designed to distinguish such recruits from 'experienced hires'

Question		Number of Staff			
		50 or fewer	51 - 250	251 - 500	More than 500
Does your organisation recruit graduates following 1-2 years post-university employment?	Yes	59.3%	76.8%	79.5%	69.4%
	No	40.7%	23.2%	20.5%	30.6%
	Total	100%	100%	100%	100%
Chi-squared test of no-association significant at 1% level					

Table 16- Recruitment of Post-experience Graduates by Firm Size (% Reporting)

To test H_5 survey respondents were also asked how satisfied they were overall with their ability to recruit engineering graduates with 1-2 years post-university work experience. On a scale of 1-5 (1 = very dissatisfied, 5 = very satisfied), the mean score returned was 2.72, suggesting some dissatisfaction with recruitment in this area[24]. There was, however, no evidence of a significant variation by firm size. H_5 is therefore rejected: SMEs are not more likely to be dissatisfied with their ability to recruit suitable post-experience graduates than are larger firms.

7.3.3 Firms that Do Not Recruit Recent Graduates

Of the organisations in the survey, 81 (19%) reported that they did not recruit graduates either directly from university or after 1-2 years of experience. Further analysis of this sub-sample was conducted to see whether this group of firms had any particular characteristics. While there was no evidence of an association with industry segment, there was clear evidence[25] of a relationship with the organisational ownership structure. The data suggest that independent UK companies are more likely not to recruit recent graduates[26]. There was also a strong association[27] between firm size and whether a firm recruited recent graduates with the data indicating that smaller firms were more likely not to recruit such graduates. Figure 8 shows the proportion of organisations by firm size that did not recruit recent graduates. Note that firms with 250 or fewer employees account for some 80% of the organisations that do not recruit recent graduates.

7.4 SMEs and Graduate Recruitment

Whilst the available data do not indicate practices regarding 'experienced hires' or PhD recruiting and therefore do not give a complete picture of the graduate in the SME, the evidence discussed above does tend to support the view that SMEs' graduate recruitment practices are different to those of larger firms. Firstly, SMEs are less likely to recruit graduates direct from university. Secondly, a higher proportion of SMEs appear to recruit graduates with some work experience than recruit directly from universities; and thirdly there is evidence to suggest that SMEs are more likely than larger firms not to recruit recent graduates at all, whether directly from university or after work experience.

[24] Result significant at the 1% level against a test value of 3.'

[25] Result significant at the 1% level.

[26] The term 'recent graduate' is used here to refer to those recruited direct from university as well as post-experience.

[27] Result significant at the 1% level.

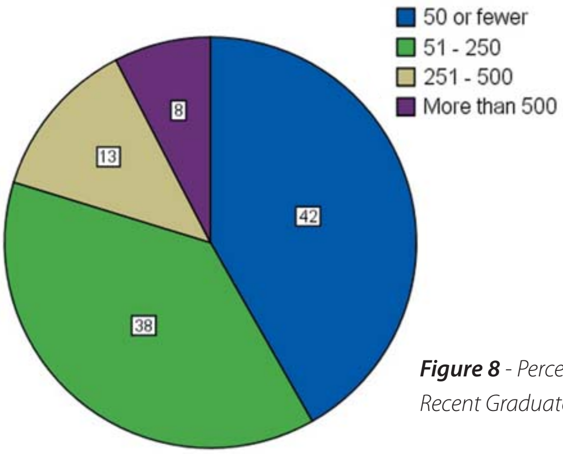

Figure 8 *- Percentage of Firms Not Recruiting Recent Graduates by Firm Size (n = 81)*

7.5 Summary

The key points from this chapter can be summarised as follows:

- SME engineering firms look for graduate engineers to have broadly similar skill sets to those sought by larger firms. For some companies, prior industry experience is seen as essential.

- The perceived quality of engineering graduates is rather mixed, with some concerns about practical application. The survey data indicate, however, no significant difference between SMEs and larger companies in satisfaction with recruitment of graduates either direct from university or after one or two years work experience.

- Examination of the differences between SMEs and larger firms indicates that larger firms are more likely to recruit engineering graduates direct from university, but this is not the case for post-experience recruitment. There is also evidence that smaller firms are less likely to recruit recent graduates than are larger companies.

- Smaller firms are less likely to offer formal graduate training schemes than larger firms.

8. The Spin-out Perspective

This chapter picks up on a number of themes covered in the previous four chapters but from the perspective of representatives of engineering-based university spin-out companies. Because of the nature of the birth of such businesses and the particular commercial framework in which they exist, it was felt that they may have a different set of skills requirements for engineering graduates and that they may face different challenges in the future. To this end seven in-depth interviews were conducted using the interview schedule used elsewhere but with additional questions to get some understanding of the spin-out context. This chapter, after describing the particular context of spin-outs, goes on to discuss the areas of similarity and difference in the needs and experiences of engineering spin-out companies.

8.1 The Spin-out Context

In some respects university spin-outs are quite different to more established SMEs and larger engineering businesses. They are set up to exploit university intellectual property (IP) which has emerged as the result of research at the institution. Such firms tend to start very small in size though evidence from the interviews suggests that growth can be substantial. The number of employees in the sample interviewed ranged from one (several of the businesses were less than a year old and therefore at a very early stage of the spin-out life-cycle) to just over 100 (for the oldest business which was just over ten years old). Where the business consisted of one individual, that person typically had a very commercial background and was not necessarily the inventor of the IP. Larger spin-outs tended to take on some of the organisational characteristics of established SMEs in terms of having a number of functional departments with a mix of engineering and scientific staff with more commercially and administratively orientated personnel. The three larger businesses were big enough to have some form of active graduate recruitment programme/mechanism. The other spin-outs were looking to recruit on an 'as needed' basis with some emphasising the need, in the early stages of the businesses development, to recruit graduates with post-university commercial and industrial experience.

Being very small or very specialised businesses means that there can be severe resource restraints. To get around this, most of the businesses tended to obtain additional resources from three main sources namely part-time paid researchers from the 'host' university, other contributors from the 'host' university and organisations with specialist skills and expertise to whom work is outsourced. Examples of the latter included research which made use of a specialist multi-million pound test facility, and the outsourcing of manufacture of the finished product. Predictably, the smaller the business the greater the reliance on the contribution from these other sources of labour.

Another key difference to established SMEs and larger businesses is the concept of an exit strategy. A number of informants referred to the exit strategy associated with spin-outs as the university and other investors at start-up seek to maximise the return on their investment within a fixed period of time, typically five years. In other words the IP would be developed and brought to market with the anticipation that in around five years or so a larger business would acquire the spin-out and the IP with which it was associated. As one interviewee put it, '… you exit at a point where there are those who might be interested in purchasing and that all parties (including the University) can make some money.' Under these circumstances the focus of the spin-out on its personnel resource needs is much more short term.

8.2 What Are Spin-outs Looking For?

The use of engineering graduates in spin-out businesses is focused very much on a research and development (R&D) role. This focus on R&D is concentrated on the continued development of the IP being spun out of the university and developing it into a state fit for market. Graduates are therefore very much concentrated on the initial phases of the product life-cycle. This is in contrast to established SMEs and larger businesses where graduates cover a much wider range of activities. Whilst such firms would like to have graduates with some commercial experience, their technical capability is perhaps seen as of greater importance – such capability is the 'overriding requirement, without a doubt.' as one director put it. This is also illustrated by the fact that there appeared to be a higher proportion of PhDs recruited to such businesses. It was also suggested by some interviewees that technical breadth was also important and, as one director stated, an ability 'to see the inter-disciplinary aspects of technology.' This view is not too dissimilar from those expressed by established SMEs and larger firms. At initial start-up the business lead in such organisations tends to be an individual with a very commercial background enabling engineers to focus on the technical aspects. Despite this emphasis on technical ability team working and communications are still seen as important skills.

Unlike other segments, spin-outs appear to maintain a very close working relationship with their parent university, indeed many continue to make use of research facilities and research students. As noted above, where engineering expertise is lacking, resources are bought in from other providers as and when needed.

The commercial awareness referred to by respondents includes a broad range of skills and abilities, many similar to those expected by SMEs and larger businesses. For example, knowledge of British and European standards, an ability to work with customers, clients, partners, colleagues who can help with solving problems or provide advice, and an awareness of timescales and costs were all seen as part of commercial awareness. Spin-out businesses also appear to place a greater emphasis on innovation and creativity. This is perhaps not surprising given the stage in both business and product life-cycles. As the CEO of one of the larger spin-outs put it: 'I think the very important thing is to be innovative. …. That is the key point of spin-offs, they are a small company, very dynamic; our competitive advantage is our employee is very innovative.'

8.3 Graduate Quality

Concerning graduate quality there was a relatively consistent message that in general terms UK graduates fitted the bill. There were however some exceptions to this. Firstly one respondent suggested that graduates from computing departments may lack the ability to innovate compared to graduates in mathematics and physics. The respondent went on to suggest that computing graduates needed a better understanding of the disciplines that computer technology is supporting – the practical application of computer science to the real world. Several interviewees suggested that the quality of UK graduates was variable with perhaps the older, more established universities providing the better graduates.

Most of the respondents had some experience of working with, and recruiting, graduates from non-UK universities. In many respects their views were not dissimilar from the views of SMEs and larger businesses. French engineering courses were praised for producing graduates with a 'deeper grounding in mathematics and basic sort of engineering fundamentals' as one informant put it. Both German and French universities were considered to produce better analytical engineers which one respondent would opt for over a UK graduate if given the choice. One interviewee considered German graduates and undergraduates to be stronger 'because they have a lot more practical training and experience through their course than British universities give.' Another interviewee, with experience of Chinese graduates, said that mathematical skills are deeper in China but they perhaps lack a broader scientific education at A-level equivalent. It was pointed out that communications for non-UK graduates can be a problem and therefore a potential barrier to their recruitment along with issues such as work and residency permits. An interesting point which emerged from one interview was the percieved greater commercial awareness of US graduates when compared to their UK or Continental European counterparts. This greater commercial awareness was seen as beneficial.

Like established SMEs and larger businesses, the standard of mathematics acquired at school was seen as an issue leading to problems with undergraduate teaching. It was suggested that in some instances work-arounds were necessary to accommodate a lack of mathematical grounding.

8.4 The Future

As companies that are exploiting new technologies, the futures of spin-out companies were seen to be influenced by the emergence of new entrants to their markets, the development of new technologies (either a technology which competes with the spin-out's technology or complements it – for example new materials) and the changing needs of their customers. To this end graduates will need to be more flexible to meet these influences.

It was also suggested by two interviewees that engineering was becoming much more inter-disciplinary. As one of the interviewees put it 'we think people with a more generalist approach and able to see the inter-disciplinary aspects of technology; these are the people we think are going to be the most important people, because the way products and developments go these days, it does tend to be much more of this inter-linking of different technologies.' The other interviewee reinforced this message.

8.5 University/Spin-out Relationships

The relationship between universities and their spin-outs appears to be a major area of distinction between spin-outs and established businesses. Because of the way spin-outs have emerged from universities it is not surprising that a very close relationship is maintained between the two organisations. Indeed one informant considered it to be a 'symbiotic' relationship. Another interviewee stated that '…there was still quite a lot of reflection back into the university…' and that '…gives a good opportunity for the graduates, or the under-graduates that are coming through to work on some of these projects.' Another informant talked of the continued benefit of research work carried out by both organisations and the career development path for students offered by the spin-out. The 'parent' university also provides a resource pool from which new personnel can be recruited as the spin-out grows.

8.6 Summary

The key points from this chapter can be summarised as follows:

- University spin-out companies have skills requirements for graduates which are broadly similar to SMEs and larger businesses. However, because of the focus of these businesses on the very early stages of the product life-cycle development, the emphasis is on technical ability and innovation.

- There is a very fertile and symbiotic relationship with the university from which the spin-out has emerged. The relationship, which may not be typical of established engineering firms, provides an expert resource and recruitment pool for the spin-off and is a means of providing students at the university with practical, technical and business experience.

Part Five: The Engineering Graduate in the Future

Part Five looks at future developments within engineering and their implications for graduate engineering skills and skill formation. The underlying logic at work here is that a firm's human capital needs depend upon its strategic requirements, and particularly upon the capabilities it needs to develop in order to compete. In terms of engineering graduates' future skill needs it is therefore logical to begin with an understanding of expectations regarding the engineering industry of the future. The first chapter in this section therefore starts with a discussion of future trends in engineering and develops a number of scenarios based on the survey data. The next chapter goes on to review possible impacts on skill needs of these developments. The final chapter of the section looks briefly at how those skills might be developed, and in particular what changes might be needed to undergraduate engineering education in the future.

9. Future Changes and Challenges in the Industry

In order to understand future skill needs, the research sought to get an understanding of future trends in the engineering industry. In general terms, the picture that emerged was one of accelerating change which was not just in technology but in other areas as well, including fundamental shifts in the structure of the engineering industry globally. One senior executive described this situation in the following terms: 'there's always been a degree of change, but when I first started the change was so slight you could hardly tell; but the last twenty to twenty-five years the rate of change has visibly increased in all respects…. You can't stand still – a skill, an activity, a method of applying engineering, even the forms of contracting, the way in which projects happen, how they're funded – you name it, it's changing all the time'.

9.1 Future Changes and Challenges in the Industry

The interview data provided an initial route to gaining an understanding of the dimensions of this changing environment.

9.1.1 Focusing on Solutions

One area of change that was expected to intensify was the focus on providing customer solutions rather than individual, pre-specified components. 'There's a sort of shift in focus from being a centre of technical excellence which you have sold to lots of people' explained one senior manager 'to being focused on all the customer's problems, pulling in whatever's required to solve them'. This trend has a number of implications. The first is the continuing emphasis on the combination of physical goods and less tangible services, a trend that has been evident in manufacturing for some time. 'Increasingly,' argued one manager, 'in the competitive world we live in, we start from the customer's process, define a solution… and then that solution manifests itself as something physical and something that's a service'. A second implication is the emphasis on providing system solutions. '[Our major customers] are not interested in single components anymore, they want systems' commented one manufacturer. A third implication is the increased complexity of the management task. An example of this is asset management, described by one respondent in the following terms: 'what we are now, we are managers of complex assets which have high capital value, long lives and degrade over time in interesting and complex ways. So that's really the process we are managing'. Linked with this is the need to work and manage complex value chains, involving a wide range of stakeholders both internal and external.

9.1.2 Complexity in Technology

A second theme that emerged was the increasing complexity of the technological domain. One aspect of this was the growing number of different technologies that could be embodied into a single product. An interviewee illustrated this point with reference to the development of a particular component: 'one device and suddenly you've gone from being just an electro-mechanical device to now covering probably six or seven different technologies'. In terms of specific technologies, a number of interviewees made specific reference to the continued growth in what one respondent described as the 'electrification' of products. Software would also become increasingly central to product design and operation. Increased complexity was also seen in systemic terms requiring engineers who were able not only to work in an environment with multiple technologies, but also to understand the social and commercial dimensions of that complexity. The skills to do this were frequently talked about in the language of systems engineering, so this can be seen as an extension of a need that is already seen in some areas.

9.1.3 The Global Industry

A third important theme was globalisation. One aspect, global recruitment, has already been touched upon but this was not the only dimension that was evident. On the product market side, several interviewees pointed to changes in the global pattern of demand requiring, for example, the setting up of local operations to serve those markets. In turn this meant employing graduates with local knowledge, including language and cultural skills.

The most dramatic changes, however, seemed to be happening on the supply side, in particular through the growth of 'offshoring' with the shift of activities to lower-cost countries. Of course this has been a feature of manufacturing for many years but it is increasingly happening in all areas of engineering. An example of the speed of change was given by one respondent's account: 'our Indian office was about 70 people at the beginning of this year, it's now 250 and it will be 400 by the end of this year, probably by the end of next year it will be 600 if not more'. Another respondent saw a similar trend: 'we're looking at a world where there are going to be resource shortage drivers that will force firms to do more and more work for UK clients overseas, and… when you back that up with significant (at least short term) cost benefits of doing so, you're going to see a turn around where quite a large part of … the design process, which used to be carried out in the UK, is now being carried out internationally'. In addition to offshoring, respondent firms also made reference to more direct competition, especially as emerging markets developed their indigenous engineering capabilities.

The potential implications for UK engineering in the future were fairly clear. 'The most significant challenge will be the demand on engineering activities in the UK… to be able to deliver the kind of value that's commensurate with their costs' commented one respondent. A similar line was taken by another senior executive when discussing offshoring plans: 'we're opening up a centre for analysis in India, where I'd expect to pay the graduates thirty percent of what I pay them here. So conversely if I were to pay graduates in this country three times what I pay graduates in India I would expect something out of that person for that salary. Without that it will be difficult over time to sustain activity over here'. One response to this was expected to be a shift in terms of the kind of activities that would be carried out in the UK. 'We'll be moving away from detailed engineering, much more to requirements capture, segmentation into different sub-systems, making sure your global suppliers can do what you get them to do even though you never meet them. Then make them all work when they come back together' suggested one interviewee. There would be an increased demand for people 'who are able to specify things rather than be responsible for the manufacturing process'. Interestingly, whilst offshoring was often seen as a possible long-term threat to UK engineering, one respondent emphasised the opportunities that were created as a result of offshoring. 'Because that dilutes your cost base significantly, we are now finding ourselves more competitive and rather than shrinking in size we're growing in size…. And that's been the pattern of the other major contractors in the UK who've got similar Indian market place back-offices…. Somewhat counter-intuitive… the scale of the operation goes up not down, but it does become much higher value-added'.

9.1.4 Sustainability

Environmental sustainability was another area which received some attention, although perhaps less than might have been expected. It was clearly an important issue for companies involved in energy and infrastructure. It was also an issue for some manufacturing companies. One executive presented an interesting view of the role of engineering within the sustainability agenda. 'Sustainability isn't a science, it's an idea and the science that will deliver solutions to sustainability is still the science we know…. It's actually, what it is, is shifting the paradigm of what the mission is for the engineer's task but the way the engineer will respond to that changed mission will be by harnessing all the techniques that we've been talking about, the skills'. Related to broader debates over sustainability and social responsibility, health and safety, and the general regulatory environment were also areas which some respondents felt were likely to become more important in the future.

9.1.5 The Innovation Imperative

A recurrent theme throughout discussion of the future of engineering was the need for innovation and creativity. This was at three levels. Firstly, it was seen as important at the level of the economy. As one executive explained 'we expect more creativity, more innovation, more excellent technical skills that… will maintain the activities in the UK will have compared to low cost countries.' 'UK based designers have to offer considerably more value in terms of creativity and pace in order to remain competitive', argued another. Secondly, innovation and creativity were important for individual firms. 'Technology innovation is where we actually see ourselves as a differentiator against anybody else in the game' argued one interviewee. Not surprisingly, this requirement also operated on a third level, that of the individual. Consequently, as will be seen in the next chapter, creativity and innovation are likely to become even more desirable characteristics of engineering graduates in the future because, as one respondent observed, 'experience is important but it doesn't – it can't – correct for innovation.'

9.2 A Scenario for the Future

In order to incorporate the insights from the interviews into the survey, a series of questions were developed to gather data on respondents' expectations regarding the future. The questions were built around dimensions of change identified in the interviews. These dimensions were:

- *Goods – Services:* the extent to which competitive advantage will be gained from either goods or services.
- *Component – System:* the extent to which competitive advantage will be gained by specialisation within the value chain (Component) or integrating activities across the value chain (System).
- *Partnership – Transaction:* the extent to which relations with other organisations will be collaborative partnerships or transactional.
- *Globalisation – Localisation:* the extent to which competitive advantage will come from location within a global or a local network.
- *Breadth – Depth:* the extent to which competitive advantage will come from greater breadth or greater depth of technical expertise.
- *Exploitation – Exploration:* the extent to which competitive advantage will come from maximising the value of existing technologies (Exploitation) or developing new technologies (Exploration).

Using a type of semantic differential scale each dimension was represented by a 7-point scale with the end points anchored by two contrasting terms (e.g. goods-services, see Figure 9). Respondents were asked to locate their company's expected position in ten years' time on each of the six dimensions. Doing so developed a possible future scenario for each respondent firm in terms of these six different dimensions.

The resulting responses were then classified using Cluster Analysis, a multivariate statistical technique which divides objects (respondents in this case) into groups called 'clusters' wherein the objects are similar to one another and different from objects in the other clusters. In this instance three such clusters were identified with differing emphases on the different dimensions. These are presented graphically in Figure 9 which plots the cluster centres on the seven-point scale of each dimension for each of the three clusters identified. Figure 9 can be interpreted as suggesting that respondent firms' perceived futures can be grouped into three groups (clusters), each with different expectations. Cluster A (n = 158) can be thought of as envisaging a future of globalised goods supply, with a tendency toward partnership-style relationships and orientation towards exploring new technologies. To some extent Cluster C (n = 177) can be thought of as the service equivalent, but with stronger emphasis on a systems orientation and partnership relationships. Cluster B (n = 93), on the other hand, located themselves in the centre in terms of all dimensions apart from one, where they appear to be more localised in their orientation. The characteristics of each of these clusters will now be explored in more detail.

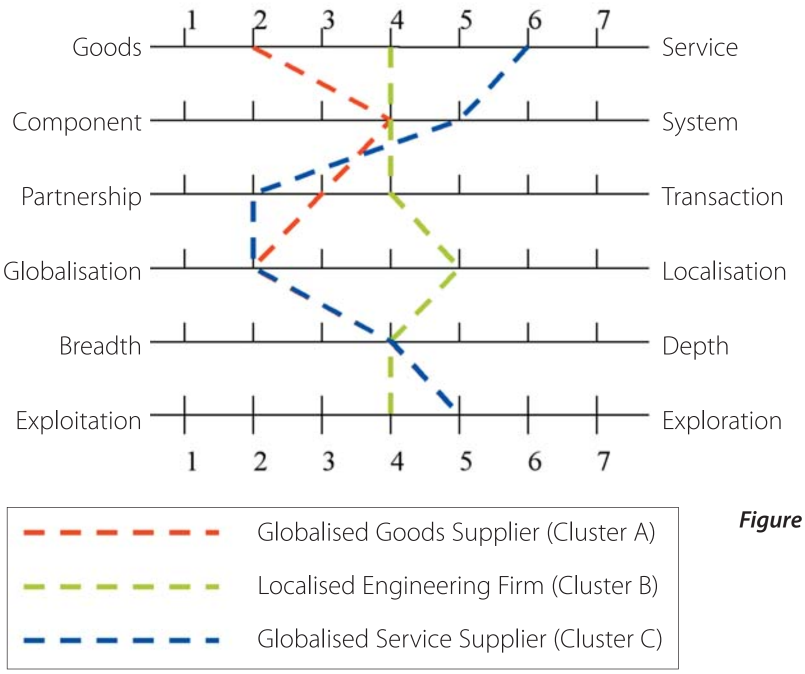

Figure 9 *- Plot of Cluster Centres*

9.2.1 The Globalised Goods Supplier (Cluster A)

Firms in this group envisage a future scenario where competitive advantage is derived primarily from the physical goods they sell. Their position within a global network is a source of competitive advantage. Relationships with other organisations are more partnership-based than transactional. These firms also tend to see competitive advantage as coming from developing new technologies, although they expect a balance between depth of technical expertise and technical breadth. Not surprisingly, organisations within this cluster are most likely to be in manufacturing, and consequently more likely to be using engineering graduates in manufacturing and production roles today than other firms. They are also more likely to be subsidiaries of UK or overseas companies than independent companies. Finally, a greater proportion of these organisations are in the size range 251-500 employees than the other clusters

9.2.2 The Globalised Service Supplier (Cluster C)

Sharing some characteristics with firms in the globalised goods supplier group, firms in this cluster perceive competitive advantage in the future coming primarily from the services they sell. They see themselves as more partnership-oriented and more as integrators within their value chains than either of the other groups but like the last group, these firms look to derive competitive advantage from within a global network. Likewise, the firms in this group have an orientation towards developing new technology. Organisations within this cluster are rather less likely to be manufacturing companies, although such firms still make up around half of the total. These firms also tend to be larger compared to organisations in the other groups; nearly half of the firms with over 500 employees are in this cluster. The proportion of graduates in the workforce is also somewhat higher in this group. Organisations in this cluster account for over half of the firms where more than 50% of the workforce are engineering graduates, and they are more likely to recruit such graduates directly than are other organisations. In turn, a higher proportion of these graduates are likely to be in roles such as project management, design, estimating, and field service than in other firms.

9.2.3 The Localised Engineering Firm (Cluster B)

Firms in this group see themselves as being positioned across the mid-point of all of the dimensions except for that of globalisation-localisation, where there is a tendency toward the latter. Organisations in this group are more likely to be independent UK companies than are those in the other groups. In fact 64.5% of this group describe themselves in this way. They also tend to be smaller; just over two-thirds (68.5%) have 250 employees or fewer. In terms of graduate employment, less than half (41.8%) recruit graduates[28] direct from university, indeed 32% do not recruit recent graduates at all. Graduates in these organisations are also less likely to be used in roles such as research and development or design than in other groups.

9.3 Future Technologies

As an indicator of which emerging technologies might be particularly significant over the next decade, an additional survey question related to the expected impact of certain technologies over the next ten years. The results are summarised in Table 17. Materials science and information and communications technology are clearly expected to have the highest impact. Other technologies mentioned included mechatronics and manufacturing technology.

Technology Area	No impact		Some impact		Significant impact	
	Count	%	Count	%	Count	%
Biotechnology	292	71.22%	79	19.27%	39	9.51%
Nanotechnology	224	55.45%	143	35.40%	37	9.16%
Materials science	47	11.01%	231	54.10%	149	34.89%
Photonics	250	63.29%	123	31.14%	22	5.57%
Information and communications technology	28	6.67%	201	47.86%	191	45.48%

Table 17 - Impact of Emerging Technologies

9.4 Summary

The key points from this chapter can be summarised as follows:

- The pace of change is expected to intensify and cover both technological and non-technological domains. Particular themes that emerge from the research are:
    - Increased need to focus on solving customer problems, including the emphasis on the service dimension of products, the growing requirement to provide system solutions, and increased complexity of the management task.
    - Growing technological complexity and interdependence at all levels
    - Globalisation affecting both demand and supply, with the rapid growth of offshoring providing a particular challenge which will force UK engineering to concentrate on higher-value adding activities.
    - The growing importance of innovation and creativity to respond to the challenges of a turbulent environment.
- Different groups of engineering firms anticipated different futures. One group can be described as global goods suppliers, focused on manufactured products and globally networked. A second group is service focused but still global. A third group, with a more local orientation, can be described as localised. Each of these groups has somewhat different demographic characteristics.

10. Implications for Future Skills Needs

This chapter explores the implications of these trends for the future skill needs of engineering graduates. From the in-depth interviews there was little evidence of any dramatic shift in requirements. For the survey it was therefore decided to build on the skills frameworks presented in Part Three in order to get a more general understanding of skill needs. The findings are presented here.

[28] The term 'recent graduate' is used as previously to refer to those recruited direct from university as well as post-experience.

10.1 The Future Need for Graduates

A useful starting point is given by the responses to the survey question which asked participants to give an overall assessment of whether the proportion of engineering graduates in their workforce was likely to increase or decrease over the next ten years. On a scale of 1 to 5, where 5 was 'increase significantly', the mean score returned was 3.70[29] which suggests an expectation that the proportion of graduates will increase in the future. Further analysis showed no significant difference according to demographic factors such as firm size or industry sector. This finding also confirms the impression gained from the interviews, where some respondents expected to recruit more graduates in order to meet future business challenges, or to address problems of an ageing workforce. Whether this translates into increased total demand for engineering graduates depends, of course, on the general growth or contraction of the industry.

Looking at future skill needs in terms of engineering disciplines, respondents were asked on a scale of 1-5 (1 = recruit significantly fewer, 5 = recruit significantly more) how they expected their organisations' recruiting needs will change over the next ten years. The results, presented in Table 18, suggest that engineering graduates in many of the disciplines included in the survey will be in somewhat greater demand. Systems engineers, electrical/electronic engineers would appear to be likely to see such an increase, followed (perhaps somewhat surprisingly) by production/manufacturing engineers and computer sciences/software engineers. Whilst some of the disciplines that are seen to be more important are those where recruitment difficulties are currently experienced this is not so in every case. A very small number of respondents indicated other disciplines that they expected to need in the future, including aeronautical/aerospace and design engineers. As noted above, whether or not the findings reported here actually lead to increased demand depends on factors not included in this survey. Nevertheless they do give an indication of the expectations of engineering firms as to what disciplines are likely to be more important for them in the future.

Type of Engineer	n	Mean	Std Deviation
Electrical/electronic	338	3.53**	0.915
Systems engineering	238	3.47**	0.992
Production/manufacturing	294	3.32**	0.956
Computer sciences/software	278	3.30**	0.908
Mechanical	379	3.27**	0.909
Chemical	63	3.19	0.859
Building services	25	3.00	1.041
Civil	39	2.97	1.013

** Significant at the 1% level against a test value of 3

Table 18 - Future Skills Needs by Engineering Discipline (1=decrease significantly, 5 = increase significantly

10.2 The Importance of Particular Skills

The research also sought to identify respondents' expectations regarding future skills needs in terms of the skill sets outlined in Part Three. Two methods were used and both are reported here. The first approach was to ask respondents to rate on a scale of 1-5 (1 = low importance, 5 = high importance) what will be the most important skills and attributes needed by the engineering graduates their organisation will expect to be recruiting in ten years' time. Six sets of skills were presented[30]. The results are summarised in Table 19, where they are presented in descending order of mean value. It is interesting to note the high importance attached to practical application, creativity and innovation, and team working.

[29] Result significant at the 1% level.

[30] Seven skill sets were used in Part Three. For this question, the skill set 'communication' was dropped since there was no evidence from the interviews that it would change in importance and there were technical reasons for preferring a smaller choice set for the later analysis.

Skill and Attribute	n	Mean	Std. Deviation
Practical application	437	4.35**	0.728
Creativity and innovation	436	4.24**	0.772
Team-working	436	4.03**	0.864
Technical breadth	433	3.88**	0.797
Theoretical understanding	437	3.87**	0.841
Business skills	434	3.36**	1.025a
*** Significant at 1% level against test value of 3*			

Table 19 - Importance of Skills in Ten Years' Time (5 = High Importance)

10.2.1 Identifying Priorities

Although Table 19 provides some interesting data, there is not much discrimination between the different skill categories. It is therefore not easy to use for understanding priorities. This problem was anticipated and therefore a second series of questions was included to investigate this central topic. These questions were based around a technique known as conjoint analysis which is used to understand respondents' underlying preference structures when choosing between options with multiple attributes. In this case the options were a series of profiles of potential recruits with differing levels (average or above average) of the six skill sets identified in Table 19. A total of eight profiles were presented, and respondents were asked to rank them on a scale of 1-8, with 1 being the profile of engineering graduate that their organisation will be most likely to need to recruit in ten years' time, and 8 being the least likely. A total of 385 useable responses were received to this question set[31].

The results are presented below. The first chart (Figure 10) shows the preferences of the total sample. As can be seen, practical application is most important, followed by theoretical understanding and creativity and innovation. Of interest is how low business skills are rated. Whilst they are also rated lowest in Table 19, the low priority accorded to them by respondents is underlined by this method. Most striking, however, is the much higher importance accorded to theoretical understanding using this method than is suggested by the results in Table 19.

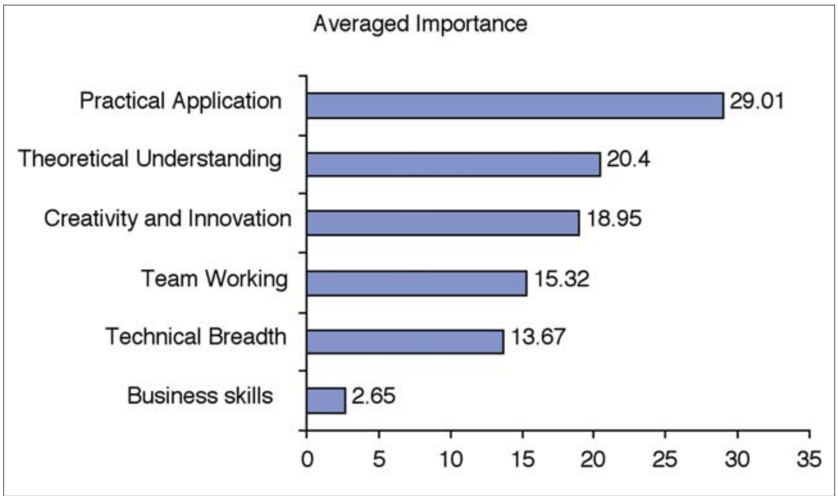

Figure 10 - Averaged Importance of Future Skills (all respondents)

10.2.2 Cluster Differences

Figure 11 presents the conjoint results by future scenario cluster (see above). There is a high degree of consistency but some suggestion that team working may be particularly important for the service-oriented firms in the globalised service supplier cluster. Given the relative importance of project management roles for graduates in these

[31] Since this is a relatively complex task, some loss was expected. Of those not completing this question, about half were left entirely blank, the remainder had tied rankings or other problems and were not included in the analysis.

organisations, and the partnership orientation of such firms, this is possibly explicable in terms of work structures. Similar importance is attached to creativity and innovation, even though firms in both the globablised clusters (A and C) saw technological development as more important than companies in the localised engineering firm cluster in their vision of the future. Interestingly, technical breadth is seen as somewhat more important for companies in the latter cluster, although there was no difference in the cluster scores on the depth-breadth dimension. Overall, however, the results in Figure 11 do suggest a striking homogeneity in future industry requirements across the clusters.

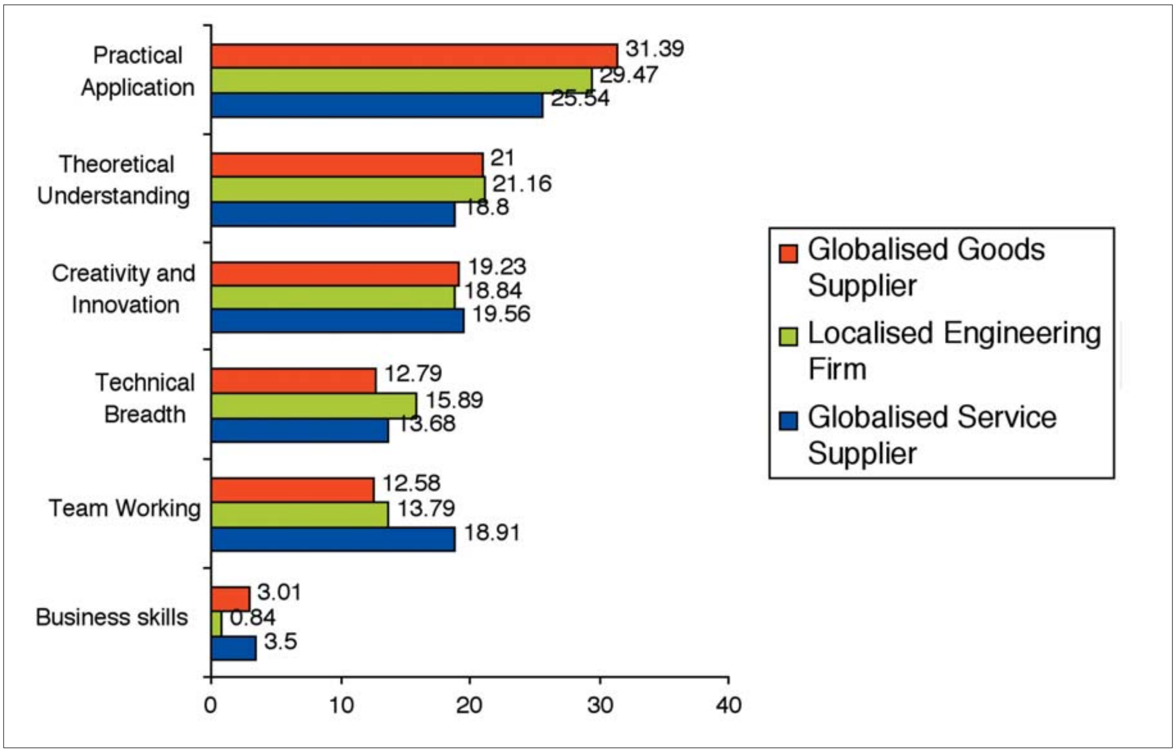

Figure 11 - Averaged Importance of Future Skills by Respondent Cluster

10.3 Interpreting Future Skills Needs

To get a better understanding of these priorities it is useful to compare these findings with the interview data.

10.3.1 Defining Skills – Technical Domain

Beginning with the technical skill set, it is not surprising, given the importance attached to practical application, that this should come out as the top priority, especially as it has also been highlighted as an area of weakness for current engineering graduates. Perhaps more unexpected is the importance attached to theoretical understanding, and the relative unimportance of technical breadth. This was certainly a recurrent theme in the interviews where the discussion of technical skills was generally around the need for a broader technological awareness. Specifically, systems engineering, broadly defined, was expected to become increasingly important. 'We want graduates that are broadened in competencies because systems engineering is important and therefore there's less need for more narrow specialisations, more need for systems engineering at a high level, especially if we're going to buy in some systems from other places' explained one senior executive. This thinking would need to extend beyond technology. 'It isn't just engineering, it's engineering and its implications on society and how you manage complexity. And being able to think in a systematic way' was how another respondent put it. The expected increase in systems engineers reported in Table 18 may reflect this requirement. However, as Table 19 shows, the need for greater technological breadth does not appear to be the view of survey respondents.

The answer, as some interviewees emphasised, may lie in the fact that this broader technological awareness should not come at the expense of understanding the fundamentals of engineering. In particular, there would still be the need for specialist knowledge acquired at university, not just generalist systems understanding. One respondent from the manufacturing sector put the trade-off in this way 'if you try to do a blanket systems engineering [course] for everybody, that won't produce the specific skill sets that you still need in the product environment'. It was also less clear whether the sort of skills being discussed in this context were best acquired at university or during a graduate's career.

There is strong agreement between both data sets, however, on the need for innovative and creative people who can deal with the complex and changing environment that was expected to characterise the industry of the future, and provide the leadership the industry would need. 'It's vitally important that we find that five or ten percent of our people who are going to have those leadership, entrepreneurial, innovative skills to make a change happen, to take it in their grasp' urged one senior executive. 'It's going to be more and more important that they are able to innovate and… self-train themselves to respond to the changing environment' argued another. 'We are going to need to employ more and more creative types, rather than just the execution types' was yet another comment. The emphasis on innovation and creativity can be linked both to the challenge of competition from overseas, and the desire to use human capital as a hedge against an unpredictable future. 'What we're certainly going to need are the leaders of the future, the people who are going to have the ability to see the future, have the innovation skills to lead us into new areas, and to undertake innovative design' was how one executive summed up the problem.

10.3.2 Enabling Skills

Interviewees suggested that interpersonal skills would also continue to be important into the future. 'I don't think personal attributes are going to be any different' suggested one interviewee, 'we need team players now and we're going to need team players in the future'. Since many companies operated globally there would also be a need for much greater inter-cultural awareness. Management of a global supply chain, for example, would require a broad range of soft skills: 'understanding how people are motivated, how you manage performance, how you build effective teams' was what was involved according to one respondent. For some interview participants there would also be an increasing demand for business skills in the future. Customer focus and commercial awareness were seen as being of increasing importance, in particular understanding the commercial context of engineering activity. 'I think the engineer of the future should say "we need specialist engineering understanding, but we are applying engineering in pursuit of a business aim"' was how one respondent put it. Nevertheless, the survey data suggest that this is seen as the least important of the skills examined.

10.4 Summary

The key points from this chapter can be summarised as follows:

- Firms expect an increase in the proportion of graduates in the workforce over the next ten years. Certain disciplines, including electrical/electronic, systems engineering are seen as likely to be of growing importance.

- There is strong evidence that the top priorities in terms of future skill needs are practical application, theoretical understanding, and creativity and innovation.

11. Developing the Engineering Graduate of the Future

The final chapter of this section looks at what research participants felt might be done to develop suitably skilled engineering graduates in the future. It draws on the interviews and the responses to an open-ended question within the survey which invited respondents to say what changes, if any, they would like to see made to university undergraduate education at UK universities to ensure that engineers have the skills needed by their organisation in the future[32]. The responses were analysed both quantitatively to give an idea of the frequency of different themes, and qualitatively to get a better understanding of the meaning attached to those themes. The resulting findings can usefully be divided into suggestions regarding curriculum improvements, and suggestions as to how courses might deliver these.

[32] A total of two-hundred and ninety-five responses were received to this question with answers varying from a single phrase such as 'project management skills' to more extensive commentary covering a range of topics.

11.1 Course Content

A recurrent theme in the interviews was the need for graduates to develop their practical skills, both technical and non-technical. 'It is about teaching engineering as an applied science, applied business science, as opposed to trying to teach it as a pure science' was how one interviewee put it. This was very strongly echoed in the survey data where nearly a quarter of respondents stressed the need for greater practical application in courses. Typical comments included the following: '[graduates] need a more realistic view of the real world and be more prepared (and capable) of involvement at a practical as well as theoretical level.' 'Concentrate more on practical applications of knowledge.' 'Practical experience. Universities are producing great computer modellers who have no practical experience.'

Despite the emphasis on practical expertise, many respondents (approximately 18%) stressed the vital importance of theoretical understanding. In fact the practical and theoretical were linked together in many responses. In some cases the concern was the need to achieve a balance between theory and practice on courses. In other cases the message was around the need for a strong theoretical basis for successful practice. 'All engineers must have a strong and sound foundation in theory,' noted one respondent, 'many of the mistakes made in practical application are due to a lack of theoretical foundation when undertaking work outside their practical experience.' A third dimension to theoretical understanding was the need for graduates to master the fundamentals of their discipline, including mathematics. 'Everybody appears to skate over the surface of mathematics, materials, physics etc, and focus on more sexy or arty stuff like computer applications, graphics, etc which may be fun but don't contribute as much long term' complained another respondent. In this connection there were several comments about the need to understand what was happening within the 'black box' of software programmes.

There was also considerable discussion of the 'enabling' skills identified earlier. These included team-working, communication skills, and business skills. Whilst the findings reported in the previous chapter suggest the primacy of the defining skills, several respondents nevertheless stressed the importance of the enabling skills. 'The attitude, team working, emotional intelligence, people skills are what makes the difference between a successful engineer and not' commented one. 'A practical team player with good, but not necessarily outstanding engineering skills, is a better person to employ than a theoretical whiz kid' suggested another. Business skills, particularly commercial awareness, were also seen as important by some. 'Increase business understanding', was one such comment, 'many graduates are technically competent but are naive to commercial challenges'. Against this, however, a few respondents were less keen to see curriculum time devoted to 'softer' skills. 'I would like to see more engineers that are really interested in physics and engineering rather than in moving into management at the earliest opportunity' argued one respondent. Another comment was particularly negative in this regard: 'there seems to be more training these days in team working and business skills that enables the average engineer to appear to be better than they actually are. Creativity and innovation come from real understanding, not group brainstorming.' What emerges from what at times seems rather contradictory data is arguably the need for graduate engineers to have all of the identified skills in some measure.

11.2 Course Delivery

Survey respondents identified two ways of enhancing course outcomes. The first was an increase in, or perhaps more accurately more relevance in, course project work. 'Practical project work, preferably with an industrial partner is necessary' argued one respondent. 'More creative, practical and market led project work,' suggested another. The second way of enhancing undergraduate education was identified as work experience. 'A year in industry or sandwich course is essential' was one view. 'More involvement with industry through sandwich courses, compulsory vacation work in industry, industrial personnel involved in lectures, practical course work etc.' was another suggestion. 'In my opinion' commented another respondent 'only graduates with significant work experience have a reasonable notion that life is not an exam with a low pass mark!' This stress on practical experience in the form of 'real life' projects and work experience is, of course, entirely consistent with the earlier discussion regarding the premium attached to practical application by employers.

11.2.1 The SME View

The SME key-informants that took part in the Phase One interviews were also asked their views on how undergraduate engineering education might be improved to meet their future requirements. Suggestions concentrated on ensuring universities understood industry needs, and ensuring that there was proper opportunity for practical experience 'a real life project, as opposed to an internal student one' as one respondent described it. Appropriate work experience, whether vacation work or sandwich courses, was seen as very important (as well as offering recruitment benefits) and some of the firms offered opportunities for placements. As one correspondent admitted, however, they were not always able to meet students expectations and the result was not always successful from either side.

11.2.2 The Spin-out View

From the perspective of the spin-out firms described in Part Four, there appeared to be no major issues with undergraduate engineering education but there were some suggestions for improvement. One respondent suggested a split between the more vocational engineering technician and the more academic theoretical engineer. Both were considered equally valuable but should be funded and developed in the most appropriate way to meet the needs of each type. Practical experience is seen as very useful for spin-outs though a clear distinction emerged between commercial awareness and being able to operate within a business environment with limited resources. Commercial awareness focuses on such issues as time and cost (essentially aspects of project management) and the needs of customers, clients and partners. Operating within the business environment covered such issues as health and safety, and operating laboratory equipment. Evidence from one interview suggested that more project-based analysis and more project-based teaching is forming part of the curriculum and is helping with the development of communications and team working. Other interviewees, however, suggested that this was not the case and that more such project-based work was needed to develop those skills. This suggests that some university courses may need to incorporate this mode of teaching into their curriculum, although attention was also drawn to the fact that there is already much to fit in to the three-year undergraduate course. Such a means of skills development was considered to be essential at doctoral level.

11.2.3 The Graduate View

Ways of improving the balance between theory and practice on engineering courses were also identified by the focus groups with recent engineering graduates. Once again project work was seen as very useful in providing the opportunity to apply theory in order to create or build something, with interdisciplinary projects proving useful in providing a complete systems view. Work placements were considered essential by some participants and particularly useful in creating opportunities to put into practice some of the theory acquired whilst at university. For example, one participant stated: 'I certainly benefited from having a six-month placement with a company which then enabled me to get stuck into a really meaty problem.' Reflecting on the benefits of industry placements another graduate explained 'I think that put me in a better position, 1) to be able to do the work at university…, and 2) at the end, to be able to go out there and sell myself and get a job.'

Alongside work placements, there was a general feeling that university-industry links could be stronger. Practical examples included modules delivered by visiting professors from industry and staff with industry experience. One individual commented that: 'the best teachers in university are the ones that have gone into industry and then come back to university.' Both this and greater ties with industry were seen as providing opportunities to enhance the relevance of theory and its practical, real-life application. In this connection it is useful to note that some of the suggestions appear relatively trivial in terms of effort and resources but were widely seen as valuable enhancements to the practical side of engineering courses. These included such things as inspecting engineering artefacts such as engine components, looking at photographs, visiting manufacturing facilities, and incorporating real case studies into course material.

11.3 Routes to Improvement

Finally, it is useful to bring together views from both the survey and the interviews as to how these changes might be brought about. Firstly, there was a general perception that more needs to be done to ensure that universities understand the needs of industry, and that these needs are reflected in the curriculum. At the same time, there was recognition that there was a need to make choices about what should be included and what should be dropped. Industry had an important role in helping universities make these choices. In this respect, some respondents referred to what they saw as examples of best practice, principally in the form of degree courses or modules that had been jointly developed between industry and university.

Secondly, interview participants appeared to acknowledge that they would have to continue, and even strengthen, their efforts with both universities and schools in terms of identifying talent, encouraging good people into engineering, and supporting the teaching of science and technology. A range of programmes was mentioned by respondents, including the Year in Industry scheme, the Power Academy and Outreach programmes. Whilst there was some recognition of Government efforts to strengthen science and technology in education, there was some concern that a number of developments in UK secondary and tertiary education could actually make it more difficult to attract students into engineering. These included university performance being judged on research rather than teaching, a funding system which encouraged universities to recruit overseas rather than UK students (including at PhD level), and a general feeling that students and schools alike tended to avoid the 'hard' subjects, of which engineering was perceived to be one.

11.4 Summary

The key points from this chapter can be summarised as follows:

- There is need for improvement in course content in terms of developing practical skills but not at the cost of ensuring students have a strong theoretical basis. Softer skills also need to continue to be included in engineering courses to prepare students for the reality of the workplace.

- More practical, business-oriented project work and work experience are two mechanisms by which these skills can be enhanced during university courses.

- The experiences of recent graduates underline the value of university staff having industry experience and, more generally, the importance of enhancing the practical aspects of course content.

- Closer university-industry ties and continuing commitment by industry are necessary to ensure that good practice is shared and to ensure that the brightest and best youngsters are attracted into engineering.

Part Six: Conclusions

Part Six begins with a short discussion of the limitations of the research, before bringing together the conclusions of the research

12. Limitations

It is important to acknowledge that, as with any other research, there are a number of limitations to take into account when assessing the findings. Firstly, there is the general methodological challenge of prediction. In this case, the research has made extensive use of expert judgement, with that expertise being collected using a range of techniques. There is a long tradition of the use of expert judgement in futures studies (Helmer and Rescher, 1959, Richter, 1982, Campbell, 1997) and such 'qualitative' forecasting techniques are particularly appropriate in situations where there is insufficient historical data for quantitative projections or there is reason to believe that the pattern of past data will not continue into the future (Makridakis et al., 1998). The combination of both in-depth interviews and survey data also offers the possibility of identifying general features and to probe the mechanisms at work behind those general features. Nevertheless, future studies are by their very nature uncertain, and this should be recognised when considering the findings.

Secondly, although the survey includes SMEs, the sample is dominated by larger engineering firms. Whilst every effort has been made to represent a range of industry views, it has to be acknowledged that there may be sectors (most obviously 'micro' businesses) whose perspectives have not been captured. Additionally, whilst the focus of the research is on the university-industry nexus, it may well be that this overlooks the role of the relationship between smaller and larger firms in the dynamic of the graduate labour market. This may be particularly important for those SMEs looking for post-experience hires. After all, those recent graduates must have gained their experience somewhere. Understanding the complexities of these relationships is outside the scope of this research, but it remains a topic worthy of investigation.

Thirdly, the focus group members were drawn from a particular segment of young engineers which may not be representative of the experience of other segments of the graduate population. Whilst the participants were drawn from a broad range of universities, disciplines, and companies, they could all be thought of as having 'landed on their feet' in terms of their careers so far. Engineering graduates in less favourable situations may have very different views.
Finally, the research has deliberately chosen to focus on firms in the engineering industry, albeit very broadly understood, rather than those firms in other sectors who employ engineering graduates whether in engineering-related roles or not. Whilst leakage of able engineers into non-engineering sectors has been a perennial complaint in the industry (and was indeed mentioned by some respondents in the current research), it was decided not to address the topic in this research. It remains an area for further research.

13. Conclusions

Each of the chapters reporting the research findings has concluded with a summary of key points. Rather than repeat those at length, this chapter attempts a higher-level synthesis of the findings.

13.1 The Engineering Graduate Today

The research paints a picture of a diverse industry operating in a complex, global environment. To operate successfully in such an environment firms are looking to recruit engineering graduates who combine technical expertise with practical ability, backed up by strong interpersonal skills, including an awareness of commercial realities. Currently it appears firms at least are generally able to find such talent. There is, however, evidence that the labour market for good engineering graduates is a tight one and firms of all sizes report the effects of skill deficiencies in engineering graduates. A general concern is the pipeline of young talent coming onto university engineering courses from school and subsequently into industry. This implies that understanding graduate skill formation involves recognising the interdependence of schools, universities, firms, and government, along with broader issues such as social attitudes to science and engineering. Such an institutionalist perspective underlines the complexity of the topic and cautions against looking for a simple fix.

13.2 The Engineering Graduate in the Future

Figure 12 synthesises the findings of the research into a visual depiction of the domain of the engineering graduate of the future. At the centre lie the defining and enabling skills and attributes that form the core competencies of the engineering graduate. Whilst other disciplines will have special skill sets, it is this combination of skills that marks out the engineering graduate and underpins the roles that industry looks to such graduates to undertake. Three such roles are identified in Figure 12 :

- The engineer as specialist recognises the continued need for engineers who are technical experts of world-class standing.

- The engineer as integrator reflects the need for engineers who can operate and manage across boundaries, be they technical or organisational in a complex business environment.

- The engineer as change agent highlights the critical role engineers must play in providing the creativity, innovation and leadership to shape the industry in an uncertain future.

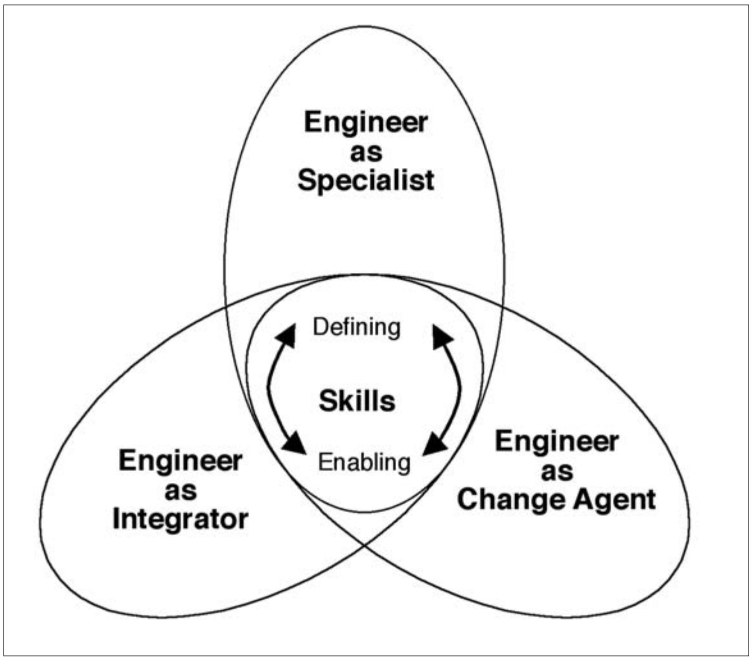

Figure 12 *- The engineering graduate in the future*

Individual engineers will more than likely focus on one of these roles; some, perhaps fewer in number, may be equally able to operate in two or more. Alternatively engineers may occupy different roles at different stages of their career. What is clear, however, is that industry will need engineering graduates in all three roles in the future.

13.3 Getting There

Reflecting the institutionalist perspective mentioned above, the findings of this research suggest that engineering graduate skill formation could be enhanced in three key areas. Firstly, further ways should be found to enhance collaboration between universities and companies to ensure that the needs of industry are understood and reflected in the curriculum. This should also include collaboration at a low-level to enhance 'realism' in teaching materials. This is not a one-way street; industry needs to recognise the challenges faced by universities in terms of curriculum design and resource constraints. Secondly, ways need to be found to strengthen graduates' practical skills, but not at the cost of their understanding of the fundamental principles of engineering and mathematics. Since work experience is seen as such a powerful route to achieving this, firms and universities need to work together to ensure that such experience is available. Finally, whilst companies must expect to continue to work with universities and schools to raise the profile of engineering as a career and attract young talent into the industry, it must be recognised that such activities may represent an opportunity cost to the industry, and one which arises because of the tight labour market for engineering graduates. In this respect it is vital to ensure that changes elsewhere in UK education do not hinder the provision of high quality undergraduate engineering education. To do so requires taking a broader, institutionalist perspective, which recognises the interconnectedness of the different parts of the education system. In particular, as this research shows, the success of undergraduate engineering education in the UK is as dependent on the engineering industry as that industry is dependent upon it.

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Appendix 1: Interview Schedule

(Statements in italics are prompts only)

1 Please describe briefly your organisation's main engineering business activities

2 What are the main engineering-related roles that engineering graduates fill in your organisation today?

3 What are the specific skills and attributes that would characterise engineering graduates filling those roles?

a. Professional engineering skills
i. Basic/fundamental engineering skills
ii. Specialist engineering skills

b. Business skills

c. Personal attributes

4 To what extent are the engineering graduates you are currently recruiting from UK universities meeting your skills requirements?

5 In what particular ways are the skill sets of engineering graduates you are currently recruiting from UK universities deficient?

6 With regard to the skills you have identified, what are your experiences of the quality of engineering graduates from non-UK universities?

7 What are your organisation's current practices in ensuring new graduate recruits are fit for their roles?

a. Recruitment

b. Induction

c. Professional development

8 Looking to the future, what do you see as the key changes in the engineering activities of your organisation/sector over the next ten years?

9 What impact do you think those changes will have on the engineering-related roles that you expect engineering graduates will perform in your organisation over the next ten years?

10 What implications do you think these changes will have for the skills and attributes of engineering graduates you will expect to recruit in ten years time?

a. Professional engineering skills

b. Business skills

c. Personal attributes

5 What do you see as the respective roles of universities, your organization and the engineering institutions in ensuring graduate engineers have those skills?

a. Role of universities

b. Role of the firm

c. Role of the Engineering Institutions

d. Any other institutions

9 What changes, if any, would you like to see in the university education of engineering students to prepare them better for your organisation's needs over the next ten years?

10 Any other comments?

Appendix 2: Focus Group Discussion Topics

1. Based on your experience, why do people study engineering at university?
2. Using the question sheet in front of you, please write down the five most important skills for you in your job role
3. Looking at this list of skills, which do you think are the most important for engineers today?
4. Based on your experience, how well do you think university engineering courses develop these skills?
5. Based on your experience, what sort of things do university engineering courses include that actually help develop these skills?
6. What sort of things might be included in university engineering courses to help develop these skills?
7. Our research so far suggests that there young engineering graduates do not get experience of applying engineering theory to practice when at university. What do you think about the balance of theory and practice in university engineering courses?
8. How could universities improve the ability of undergraduates to apply engineering theory to engineering practice at work?
9. Thinking about your future career, and using the question sheet in front of you, please write down the three most important skills you think you will need to develop over the next 5-10 years and how you will develop those
10. Looking at this list of skills, which do you think will be the most important for engineers in the future?

Appendix 3: Questionnaire

HENLEY

The Royal Academy of Engineering

Educating Engineers for the 21st Century

Introduction

Many thanks for taking the time to complete this survey which Henley Management College is conducting on behalf of the Royal Academy of Engineering to investigate what industry requires of engineering graduates now and in ten years time. The aim of this survey is to capture the views of industry on this vital topic.

Please note that the term 'engineering graduates' refers throughout to those holding Bachelors or Masters Degrees in engineering. Unless otherwise stated, it refers to graduates of UK universities.

The survey is in eight sections and should take no longer than 25 minutes to complete.

All the information you provide will be treated in confidence and will not be made available to any person outside this research project. Any reports will be based on aggregated, anonymous data.

Internal Use Only:	Returned:	☐☐ ☐☐ ☐☐☐☐
	Reference:	

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Section I: Current Graduate Recruitment Direct from University

This section asks for information regarding your organisation's employment of engineering graduates. 'Your organisation' refers to the principal business unit in which you work.

1. Does your organisation recruit engineering graduates direct from UK universities? ☐ Yes ☐ No

If your answer to this question was No, please go to Section V

2. On average, how many engineering graduates does your organisation recruit each year (please tick the most appropriate)?

☐ Fewer than 1 ☐ 1-2 ☐ 3-5 ☐ 6-10 ☐ 11-20 ☐ More than 20

3. In what roles do you use engineering graduates within the first two years of their recruitment (please tick all that apply)?

☐ Research and Development
☐ Design
☐ Manufacture/production
☐ Field service
☐ Sales
☐ Line management
☐ Project management
☐ Procurement
☐ Estimating
☐ Quality
☐ Health & Safety
☐ Other

Section II: The Quality of UK Engineering Graduates

This section asks for your views on the supply of suitably qualified engineering graduates direct from UK universities.

4. Please indicate below whether you are experiencing difficulties in recruiting newly qualified engineering graduates from the following disciplines (please tick all that apply):

Engineering Discipline	**Do not recruit**	**Not a problem to recruit**	**Difficult to recruit**
Building services	☐	☐	☐
Chemical	☐	☐	☐
Civil	☐	☐	☐
Computer science/software	☐	☐	☐
Electrical/Electronic	☐	☐	☐
Mechanical	☐	☐	☐
Production/manufacturing	☐	☐	☐
Systems Engineering	☐	☐	☐
Other *please specify*			☐

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5. On a scale of 1-5 (1 = very dissatisfied; 5 = very satisfied) how satisfied is your organisation with the following skills and attributes of newly qualified engineering graduates from UK universities?

Skill/Attribute	Very dissatisfied		Neither satisfied nor dissatisfied		Very satisfied
Theoretical understanding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Practical application	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Technical breadth	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Communications	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Team-working	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Creativity and innovation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Business skills	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

6. Overall, on a scale of 1-5 (1 = very dissatisfied; 5 = very satisfied) how satisfied is your organisation with its ability to recruit engineering graduates of suitable quality from UK universities?

Very dissatisfied		Neither satisfied nor dissatisfied		Very satisfied
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

7. If your organisation has problems recruiting engineering graduates of suitable quality from UK universities, what impact are these skills deficiencies having on your organisation (please tick all that apply)?

Areas of impact of skills deficiencies

- ☐ Delays in developing new products
- ☐ Delays to goods or services delivery
- ☐ Restrictions on growth
- ☐ Difficulties with quality
- ☐ Other *please specify*
- ☐ Increased operating costs
- ☐ Increased recruiting costs
- ☐ Difficulties with technological change
- ☐ No significant impact

8. If your organisation has problems recruiting engineering graduates of suitable quality from UK universities, what actions are being taken in response (please tick all that apply)?

Actions taken in response to skills deficiencies

- ☐ Increasing salaries
- ☐ Increasing training of existing staff
- ☐ Remedial training of newly-recruited engineering graduates
- ☐ Using non-graduates in graduate roles
- ☐ Intensifying recruitment activities
- ☐ Use of agency engineers
- ☐ Recruiting from overseas universities
- ☐ Relocating work to offshore subsidiaries
- ☐ Outsourcing work to third parties offshore
- ☐ Outsourcing work to UK-based third parties
- ☐ None of the above

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Section III: The Quality of Engineering Graduates from Overseas

This section asks for your views on the quality of engineering graduates from overseas universities.

9. Does your organisation recruit engineering graduates direct from overseas universities for work in the UK?

☐ Yes ☐ No

If your answer to this question was No, please go to Section IV

10. Overall, on a scale of 1-5 (1 = significantly worse; 5 = significantly better) how does your organisation rate the quality of engineering graduates from overseas universities compared to those from UK universities?

Graduates from overseas universites Significantly worse		About the same		Graduates from overseas universites Significantly better
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Section IV: Engineering Graduate Recruitment and Development

This section asks about your organisation's practices regarding the recruitment and development of engineering graduates who enter your organisation direct from university.

11. What methods does your organisation currently use to recruit engineering graduates (please tick all that apply)?

Recruitment method

- ☐ Liaise with schools to identify suitable candidates
- ☐ Liaise with universities to identify suitable candidates
- ☐ Careers fairs
- ☐ Advertising
- ☐ Recruitment agencies
- ☐ Knowledge Transfer Partnership
- ☐ Year in Industry scheme
- ☐ Offer work experience to identify suitable candidates
- ☐ Sponsor technicians on university courses
- ☐ Sponsor school leavers on university engineering courses
- ☐ Word of mouth
- ☐ Other *please specify* ______

12. Some engineering undergraduates gain work experience before or during their university course. Please indicate below the extent to which different types of experience make such graduates more likely to be recruited by your organisation compared to a candidate with no such experience:

Type of Work Experience	No difference	More likely to recruit	Significantly more likely to recruit
Year in Industry scheme	☐	☐	☐
Engineering work experience prior to university	☐	☐	☐
Engineering degree sandwich course	☐	☐	☐
Engineering work experience during vacations	☐	☐	☐
Non-engineering work experience	☐	☐	☐
Gap year prior to or after attending university	☐	☐	☐

13. What level of engineering degree (e.g. BEng or MEng) does your organisation prefer to recruit (please tick the most applicable option)?

Exclusively Bachelors	Primarily Bachelors	No Preference	Primarily Masters	Exclusively Masters
☐	☐	☐	☐	☐

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14. What types of training and development scheme does your organisation offer engineering graduates after they join (please tick all that apply)?

Type of Scheme

- ☐ Formal company graduate training scheme
- ☐ Formal training scheme accredited by an Engineering Institution
- ☐ Monitored Professional Development Scheme (MPDS)
- ☐ Masters-level engineering qualification programme
- ☐ Formal mentoring scheme
- ☐ Formal training or development scheme
- ☐ No formal scheme

15. In what areas does your organisation offer training for engineering graduates after they join (please tick all that apply)?

Area

- ☐ Technical training
- ☐ Business and management training
- ☐ Personal development
- ☐ None of the above

16. From the perspective of your organisation, how important is it on a scale of 1-5 (1 = very unimportant; 5 = very important) for engineering graduates to obtain Chartered status?

Very unimportant ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 **Very important**

Section V: Recruitment of Recent Graduates

Some organisations may prefer to recruit engineering graduates only after they have had a period of 1-2 years' engineering experience rather than direct from university. This section asks for information about your organisations' practices in this respect.

17. Does your organisation recruit engineering graduates following 1-2 years post-university engineering employment? ☐ Yes ☐ No

If your answer to this question was No, please go to Section VI

18. Please indicate below whether you are experiencing difficulties in recruiting recent engineering graduates from the following disciplines (please tick all that apply):

Engineering Discipline	Do not recruit	Not a problem to recruit	Difficult to recruit
Building services	☐	☐	☐
Chemical	☐	☐	☐
Civil	☐	☐	☐
Computer science/software	☐	☐	☐
Electrical/Electronic	☐	☐	☐
Mechanical	☐	☐	☐
Production/manufacturing	☐	☐	☐
Systems Engineering	☐	☐	☐
Other *please specify*			☐

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19. Overall, on a scale of 1-5 (1 = very dissatisfied; 5 = very satisfied) how satisfied is your organisation with its ability to recruit engineering graduates with 1-2 years' engineering-related post-university work experience?

Very dissatisfied		Neither satisfied nor dissatisfied		Very satisfied
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Section VI: A Scenario for the Future

This section asks you to think about the future direction of your organisation within its main business sector ten years ahead.

The set of questions below identify possible dimensions of a future scenario for your organisation. Using the scale below, tick one box for each dimension listed. Tick the box that reflects your opinion of the position on each continuum that will best describe your organisation in ten years time.

	Tending towards			<— Balance —>			Tending towards	
20. **Goods** Competitive advantage will be gained from the physical goods we sell	☐	☐	☐	☐	☐	☐	☐	**Services** Competitive advantage will be gained from the services we sell
21. **Component** Competitive advantage will be gained by specialisation within the value chain	☐	☐	☐	☐	☐	☐	☐	**System** Competitive advantage will be gained by integrating activities across the value chain
22. **Partnership** Relations with other organisations will be long-term, collaborative partnerships	☐	☐	☐	☐	☐	☐	☐	**Transaction** Relationships with other organisations will be transactional
23. **Globalisation** Competitive advantage will come from our position in a global network	☐	☐	☐	☐	☐	☐	☐	**Localisation** Competitive advantage will come from our position in a local network
24. **Breadth** Competitive advantage will come from a greater breadth of technical expertise	☐	☐	☐	☐	☐	☐	☐	**Depth** Competitive advantage will come from greater depth of technical expertise
25. **Exploitation** Competitive advantage will come from maximising the value of existing technologies	☐	☐	☐	☐	☐	☐	☐	**Exploration** Competitive advantage will come from developing new technologies

26. What do you think will be the key drivers for change in your main business sector over the next ten years?

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27. How big an impact do you think developments in the following technologies will have on the skills your organisation will be looking for from engineering graduates over the next ten years?

Technology	No impact	Some impact	Significant impact
Biotechnology	☐	☐	☐
Nanotechnology	☐	☐	☐
Materials science	☐	☐	☐
Photonics	☐	☐	☐
Information and communications technology	☐	☐	☐
Other *please specify*		☐	☐

Section VII: Future Skills Needs of Engineering Graduates

This section asks you to think about the skill sets needed by the engineering graduates your organisation will be recruiting ten years ahead.

28. Reflecting on the future scenario you have just been considering, what do you think on a scale of 1-5 (1 = low importance, 5 = high importance) will be the most important skills and attributes needed by the engineering graduates your organisation will expect to be recruiting in ten years time?

PLEASE TRY TO USE THE FULL RANGE OF THE SCALE WHEN SCORING THESE SKILLS AND ATTRIBUTES

Skill/Attribute	Low importance				High importance
Theoretical understanding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Practical application	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Technical breadth	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Team-working	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Creativity and innovation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Business skills	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

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29. Below are eight profiles of engineering graduates. Each profile has a different combination of the level of attainment in the skills and attributes listed in the previous questions. The level of attainment is either *Average* or *Above Average*. Please look at each profile and then, thinking about your organisation's requirements ten years ahead, rank them from 1 to 8, with 1 being the profile of engineering graduate your organisation is most likely to need to recruit in ten years' time, and 8 being the least likely.

PLEASE ENSURE THERE ARE NO TIES

Profile	Skill/Attribute	Level	Rank
Engineering Graduate Profile Number 1	Theoretical Understanding Practical Application Technical Breadth Team Working Creativity and Innovation Business Skills	*Above Average* *Above Average* *Above Average* *Average* *Average* *Above Average*	Rank ☐
Engineering Graduate Profile Number 2	Theoretical Understanding Practical Application Technical Breadth Team Working Creativity and Innovation Business Skills	*Average* *Average* *Average* *Average* *Average* *Average*	Rank ☐
Engineering Graduate Profile Number 3	Theoretical Understanding Practical Application Technical Breadth Team Working Creativity and Innovation Business Skills	*Above Average* *Average* *Average* *Above Average* *Average* *Above Average*	Rank ☐
Engineering Graduate Profile Number 4	Theoretical Understanding Practical Application Technical Breadth Team Working Creativity and Innovation Business Skills	*Above Average* *Average* *Above Average* *Above Average* *Above* Average *Average*	Rank ☐
Engineering Graduate Profile Number 5	Theoretical Understanding Practical Application Technical Breadth Team Working Creativity and Innovation Business Skills	*Average* *Above Average* *Above Average* *Above Average* *Average* *Average*	Rank ☐
Engineering Graduate Profile Number 6	Theoretical Understanding Practical Application Technical Breadth Team Working Creativity and Innovation Business Skills	*Above Average* *Above Average* *Average* *Average* *Above Average* *Average*	Rank ☐
Engineering Graduate Profile Number 7	Theoretical Understanding Practical Application Technical Breadth Team Working Creativity and Innovation Business Skills	*Average* *Average* *Above Average* *Average* *Above Average* *Above Average*	Rank ☐
Engineering Graduate Profile Number 8	Theoretical Understanding Practical Application Technical Breadth Team Working Creativity and Innovation Business Skills	*Average* *Above Average* *Average* *Above Average* *Above Average* *Above Average*	Rank ☐

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30. In terms of the engineering disciplines, on a scale of 1-5 (1 = recruit significantly fewer; 5 = recruit significantly more), how do you think your organisation's recruiting needs for engineering graduates in particular disciplines will change over the next ten years?

Engineering Discipline	Do not recruit	Recruit significantly fewer		Recruit about the same		Recruit significantly more
Building services	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Chemical	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Civil	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Computer science/software	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Electrical/electronic	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Mechanical	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Production/manufacturing	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Systems Engineering	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other *please specify*	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

31. Compared to today, on a scale of 1-5 (1 = decrease significantly; 5 = increase significantly), how do you expect the proportion of engineering graduates in your workforce will have to change in your organisation to compete successfully in ten years time?

Decrease significantly		About the same		Increase significantly
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

32. What changes, if any, would you like to see made to university undergraduate engineering education at UK universities to ensure that engineers have the skills needed by your organisation in the future?

Section VIII: About You and Your Organisation

This final section asks you for some background details about you and your organisation. As before, 'your organisation' refers to the principal business unit in which you work.

33. Please indicate your organisation's ownership structure:

- ☐ Independent UK company
- ☐ Subsidiary of UK Company
- ☐ Subsidiary of non-UK Company
- ☐ None of the above

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34. What is the annual sales turnover of your organisation (£ 000s)?

- ☐ £1 - £499
- ☐ £500 - £1,999
- ☐ £2,000 - £4,999
- ☐ £5,000 - £9,999
- ☐ £10,000 - £24,999
- ☐ £25,000 - £49,999
- ☐ More than £50,000

35. How many staff (full-time equivalents) does your organisation currently employ?

☐ 1-20 ☐ 21-50 ☐ 51-250 ☐ 251-500 ☐ More than 500

36. What proportion of the staff are engineering graduates?

☐ 0-5% ☐ 6-10% ☐ 11-20% ☐ 21-50% ☐ 51-100%

37. What is the primary sector in which your organisation operates (please tick the one that best applies)?

- ☐ Construction
- ☐ Engineering services
- ☐ Extractive
- ☐ Manufacturing
- ☐ Telecommunications
- ☐ Transport
- ☐ Utilities
- ☐ Other *please specify* [ ]

38. Where is the majority of your organisation's UK engineering staff employed (please tick the one that best applies)?

- ☐ North East England
- ☐ North West England
- ☐ Yorkshire and the Humber
- ☐ East Midlands
- ☐ West Midlands
- ☐ East of England
- ☐ London
- ☐ South East England
- ☐ South West England
- ☐ Scotland
- ☐ Wales
- ☐ Northern Ireland

39. What is your job title?

- ☐ Chairman
- ☐ CEO/Chief Executive
- ☐ Managing Director/General Manager
- ☐ Engineering/Technical/R&D Director
- ☐ HR Director/Manager
- ☐ Other Divisional Director/Manager
- ☐ Graduate Recruitment Manager
- ☐ Other *please specify* [ ]

If you would like to be kept informed of the progress of this research please provide contact details below:

Company name and address
please print [ ]

Contact e-mail
please print [ ]

Thank you for completing this survey

1681070597

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