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ABSTRACT

Cyclical and structural issues in engineering skills formation in Great Britain were studied through a review of recent employment patterns, income patterns, employment projections, recent trends in education and training, and recent developments in technology and work organization. The review focused on the following issues: (1) the extent and nature of mismatches between the supply of and demand for engineering skills; (2) the extent to which engineering skill problems are cyclical as opposed to structural; and (3) the adequacy of current arrangements for engineering education and training. The following were among the main conclusions: (1) engineering skill problems are most apparent when they manifest in the form of external recruitment difficulties at the peak of each business cycle; (2) long-term trends in training levels and recruitment difficulties in the past 3 decades reflect structural rather than merely cyclical weaknesses in the British system of engineering training; (3) recent changes in markets and work organizations have significantly increased engineering employers' expectations of graduates; and (4) one way to expand modern apprenticeship (MA) numbers would be to develop preapprenticeship courses to prepare underqualified 16- and 17-year-olds for later entry to MA schemes. (Fourteen tables/figures are included. The bibliography lists 34 references.) (MN)

# Engineering Skills Formation in Britain: Cyclical and Structural Issues



Skills Task Force Research Paper 7

# Skills Task Force
# Research Paper 7

# Engineering Skills Formation in Britain: Cyclical and Structural Issues

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## Skills Task Force Research Group

### Foreword

The Secretary of State for Education and Employment established the Skills Task Force to assist him in developing a National Skills Agenda. The Task Force has been asked to provide advice on the nature, extent and pattern of skill needs and shortages (together with associated recruitment difficulties), how these are likely to change in the future and what can be done to ease such problems. The Task Force is due to present its final report in Spring 2000.

The Task Force has taken several initiatives to provide evidence which can inform its deliberations on these issues. This has included commissioning a substantial programme of new research, holding consultation events, inviting presentations to the Task Force and setting up an academic group comprising leading academics and researchers in the field of labour market studies. Members of this group were commissioned to produce papers which review and evaluate the existing literature in a number of skills-related areas. The papers were peer-reviewed by the whole group before being considered by members of the Task Force, and others, at appropriate events.

This paper is one of the series which have been commissioned. The Task Force welcomes the paper as a useful contribution to the evidence which it has been possible to consider and is pleased to publish it as part of its overall commitment to making evidence widely available.

However, it should be noted that the views expressed and any recommendations made within the paper are those of the individual authors only. Publication does not necessarily mean that either the Skills Task Force or DfEE endorse the views expressed.

## Introduction

1. Engineering skills have traditionally occupied a central position in training policy discussions, partly because of their pervasiveness throughout different sectors of the British economy and partly because of the long lead-times required to produce these skills at both intermediate (craft and technician) and university graduate levels.

2. As of June 1998, some 1.87 million people were employed in the core sectors of engineering manufacturing (metal products, mechanical engineering, electrical and electronic engineering, transport equipment), down 18% in the last ten years (Table 1). The skills and knowledge of professional engineers and engineering technicians and craftspeople (especially engineering maintenance skills) are also widely utilised in other industries: for example, as Table 2 shows, manufacturing industry actually accounted for less than half the people classified by occupation to skilled engineering trades in the last Census -- other leading employers were the construction, transport, distribution and energy industries.

3. The aim of this paper is to assess the main supply and demand issues regarding engineering skills, for example:

    - What is the extent and nature of any mismatches between supply of and demand for engineering skills?

    - To what extent are engineering skill problems primarily cyclical as opposed to structural in nature?

    - Are the current arrangements for engineering education and training adequate in terms of both the quality and quantity of skills that are required?

4. The paper is ordered as follows: Section 2 surveys recent evidence on engineering recruitment difficulties and skill gaps, making some effort to distinguish between those skill gaps which have been identified by employers and others which may be described as 'concealed' or 'latent' skill gaps. Section 3 explores the cyclical and structural aspects of engineering skill problems. Section 4 briefly considers the impact on engineering skill requirements of recent changes in technology and work organisation. Section 5 reports on recent trends on the education and training supply-side of the market for engineering skills. Section 6 summarises the main conclusions which emerge from the paper.

| Table 1 Employment in engineering manufacturing sectors, United Kingdom, June 1998 | | | |
|---|---|---|---|
| | TOTAL EMPLOYMENT | % women in 1998 | Est. change in total employment since 1988 (%) |
| Basic metal and metal products | 564100 | 14.5 | -18.0 |
| Mechanical engineering (machinery and machine tools) | 394300 | 16.9 | -19.7 |
| Electrical, electronic and instrument engineering | 508400 | 31.7 | -14.2 |
| Motor vehicles, aerospace and other transport equipment | 401400 | 11.1 | -19.0 |
| TOTAL | 1868200 | 19.0 | -17.6 |

Source: DfEE, Labour Market Trends, December 1998, Tables B12 and B13

| Table 2 Employment of people classified to 'skilled engineering trade' occupations, analysed by industry, Great Britain, 1991 | |
|---|---|
| INDUSTRY: | Percent of total employment |
| Manufacturing metal etc | 38.5 |
| Construction | 14.0 |
| Transport | 12.2 |
| Distribution and catering | 8.5 |
| Energy and water | 7.1 |
| Other manufacturing | 6.7 |
| Mining | 4.7 |
| Banking and finance, etc | 3.3 |
| Other sectors or not known | 5.0 |
| TOTAL | 100.0 |

Source: OPCS, 1991 Census, Report for Great Britain, London: HMSO, 1993, Table 76.

## Recruitment difficulties and skill gaps

### Recent survey evidence on recruitment difficulties

5. The most detailed recent information on the labour market for engineering skills comes from a survey of the engineering manufacturing industry carried out by the Engineering and Marine Training Authority (EMTA) in the first quarter of 1998, and need be only briefly summarised here. It found that approximately half of engineering establishments which had sought to recruit new or replacement staff in the previous 12 months had experienced difficulties in filling vacancies (Table 3). This equates to roughly a third of all establishments in the survey and is broadly consistent with the 23-24% of engineering respondents to CBI surveys in October 1997 and January 1998 who reported that skilled labour constraints were likely to limit their output over the next four months (a more restrictive definition of 'recruitment

difficulty' than that used in the EMTA survey). By October 1998 the proportion of engineering respondents to the CBI survey reporting anticipated skill constraints on output had dropped to 13%, reflecting a slowdown in output and new orders during 1998 (EEF, 1998).[1]

Table 3 Incidence of hard-to-fill vacancies in engineering manufacturing industry, January-March 1998, analysed by sector and occupation

| | | Main occupations affected by recruitment difficulties: (% of hard-to-fill vacancies) | | | | | |
|---|---|---|---|---|---|---|---|
| SECTOR: | % of recruiting establishments reporting hard-to-fill vacancies | Professional engineers | Technicians | Craftsmen and Women | Plant and machine operators | Other occupations | TOTAL |
| Basic metal manufacture | 41 | 8 | 6 | 54 | 24 | 8 | 100 |
| Metal products | 52 | 5 | 5 | 53 | 29 | 8 | 100 |
| Mechanical engineering | 50 | 9 | 7 | 49 | 18 | 17 | 100 |
| Electronics | 42 | 21 | 19 | 28 | 18 | 14 | 100 |
| Electrical engineering | 46 | 11 | 13 | 30 | 28 | 18 | 100 |
| Motor vehicles | 58 | 12 | 10 | 46 | 21 | 11 | 100 |
| Aerospace | 55 | 6 | 17 | 42 | 28 | 7 | 100 |
| Other transport equipment | 37 | 9 | 11 | 57 | 17 | 6 | 100 |
| ALL SECTORS | 49 | 10 | 9 | 45 | 23 | 13 | 100 |

Source: EMTA, 1998 Labour Market Survey of the Engineering Industry in Britain, Tables 5.2 and 5.3.

6. As Table 3 shows, the highest proportions of establishments reporting hard-to-fill vacancies in the EMTA survey were in craft-intensive sectors such as motor vehicles, aerospace, metal products and mechanical engineering. Craft positions such as machine setters, skilled sheet metal workers and electricians accounted for roughly 40-50% of all hard-to-fill vacancies in those sectors. Other notable areas of recruitment difficulty were machine operators (in all sectors), technicians in electronics and aerospace and professional engineers in the electronics industry. All sizes of firm had been fairly similarly affected by recruitment difficulties of one kind or another. Regional variation largely reflected the geographical distribution of different types of engineering activity, for example, difficulties in recruiting craft-skilled employees were highest in regions where craft-intensive industries are concentrated (for example, Wales, the Midlands and the South West) and lowest in the South East which has a relatively small proportion of craft-intensive establishments (EMTA, 1998: 41-44).

7. The main area of engineering skills and knowledge for which detailed information exists on the extent of recruitment difficulties outside engineering

[1] Refers to Engineering & Allied Industries (Table 13 in quarterly CBI Industrial Trends Surveys).

manufacturing as well as inside it is at graduate level. Mason (1999) reports on a survey of employers of engineering, science and IT graduates in a mix of manufacturing and service sectors in the first quarter of 1998. As Table 4A shows, some 35% of enterprises in electronics manufacturing had sought to recruit technical graduates of one kind or another in the previous three years and found some difficulties in meeting their recruitment targets. In mechanical engineering and in three leading service industries (research services, computer services and financial services) the proportion of enterprises reporting similar difficulties ranged from 19-26%. In the case of the three service sectors the single most important discipline in shortage was computer science/IT rather than any engineering subject (Table 4B). However, the study found that the problems electronics companies had in recruiting electronic engineering graduates were accentuated by competition from higher-paying employers in computer and financial services who were both willing and able to fill IT vacancies with electronics graduates. By contrast, computing/IT graduates are generally not suitable candidates for electronic engineering work. The special case of electronic engineering graduates is discussed further below (Section 5.2).

Table 4 Extent and nature of difficulties in recruiting technical graduates in selected industries

A: Responses to question: How easy have you found it to meet your recruitment targets or needs for graduates in the past three years? *Percentage of enterprises replying:*

| Sector: | Graduate recruitment: Very difficult | Quite difficult | Quite/very easy | No recruitment of graduates in this period | TOTAL | *n=* |
|---|---|---|---|---|---|---|
| Electronics | 12 | 23 | 27 | 38 | 100 | *87* |
| Machinery | 5 | 21 | 38 | 35 | 100 | *79* |
| R & D services | 8 | 18 | 34 | 40 | 100 | *50* |
| Computer services | 7 | 18 | 43 | 32 | 100 | *88* |
| Financial services | 3 | 16 | 42 | 39 | 100 | *71* |

B: Nature of recruitment difficulties

| Sector: | Main technical disciplines in which difficulties have occurred | Main areas of expertise in which difficulties have occurred |
|---|---|---|
| Electronics | 1. Electronic engineering<br>2. Computer science/IT | 1. Electronics<br>2. Software engineering |
| Machinery | 1. Mechanical engineering | 1. Electronics<br>2. Software/IT |
| R&D services | 1. Diverse engineering and science disciplines | 1. Software/IT |
| Computer services | 1. Computer science/IT | 1. Software/IT |
| Financial services | 1. Computer science/IT | 1. 'Relevant knowledge/experience'<br>2. IT/Electronics |

Source: Mason (1999).

## Skill gaps within engineering companies

8. Just under a third of the engineering establishments surveyed by EMTA reported that there was a gap between the current skills of their workforce and the skills required to meet business objectives (EMTA 1998:51). This is much the same proportion as those who had experienced recruitment difficulties in the previous 12 months, although there is no published information on the extent of overlap between the two groups of employers. The areas of deficiency underlying reported skill gaps embraced a wide range of practical skills (defined as 'ability to carry out job-related tasks') and deficiencies in generic skill areas such as computer literacy, communication skills, problem-solving skills and 'personal skills' (such as 'motivation, ability to fit in').

Table 5 Areas of skill deficiency in existing workforce reported by engineering employers, analysed by sector (numbers in brackets are percentages of establishments reporting skill gaps)

| | | | |
|---|---|---|---|
| Metal products | 1. Practical skills (68)<br>2. Multi-skilled employees (41)<br>3. Skilled craftspeople (40)<br>4. Computer literacy (30)<br>5. Communication skills (24)<br>6. Personal skills (23) | Electrical engineering | 1. Practical skills (55)<br>2. Computer literacy (42)<br>3. Communication skills (39)<br>4. Management skills (35)<br>5. Personal skills (32)<br>6. Skilled craftspeople (29) |
| Mechanical engineering | 1. Practical skills (63)<br>2. Computer literacy (41)<br>3. Communication skills (34)<br>4. Management skills (29)<br>5. Skilled craftspeople (26)<br>6=. Personal skills (25)<br>6=. Problem-solving skills (25) | Motor vehicles | 1. Practical skills (67)<br>2. Multi-skilled employees (44)<br>3. Problem-solving skills (42)<br>4=. Communication skills (41)<br>4=. Computer literacy (41)<br>4=. Personal skills (41) |
| Electronics | 1. Practical skills (53)<br>2. Computer literacy (39)<br>3. Communication skills (34)<br>4. Management skills (33)<br>5. Personal skills (32)<br>6. Problem-solving skills (27) | Aerospace | 1. Practical skills (54)<br>2=. Computer literacy (38)<br>2=. Problem-solving skills (38)<br>4. Skilled craftspeople (35)<br>5. Management skills (32)<br>6. Communication skills (29) |

Source: EMTA (1998, Table 6.4)

9. Sectoral data, unweighted for employment size of establishments, show a strong emphasis across all sectors on deficiencies in practical skills and concerns about computer literacy also feature highly in most sectors (Table 5). EMTA (1998:52) notes that, while shortcomings in practical skills were reported by all sizes of establishment, concerns about weaknesses in management skills and different kinds of generic skill were more prominent in

large establishments than in small ones. Although craft occupations were the most prominent area of reported difficulty in external recruitment (Table 3), less than half the respondents reporting a skills gap specifically attributed this to a lack of skilled craftspeople (even in notably craft-intensive sectors such as aerospace and mechanical engineering).

10. The implication of the EMTA findings is that roughly two thirds of survey respondents believed that the skills of their existing workforce were sufficient to meet their business objectives. This is lower than the 82% of respondents expressing similar satisfaction in the *Skill Needs in Britain 1997* survey of employers across the whole economy (IFF, 1998)[2] but, taken at face value, it still suggests that workforce skills are not a problem area for a large majority of engineering employers. However, any such assessment presupposes that the business objectives set by most employers are consistent with future success in competitive markets and that they have a full appreciation of the skill levels required to maintain or increase market share in their main product areas. If these two conditions do not hold, then a proportion of British engineering firms may conceivably be subject to 'concealed' or 'latent' skills gaps which cannot be identified through the standard survey questions which address this topic.

11. In recent years some light has been shed on these issues by cross-country comparisons of matched samples of engineering establishments which have suggested that relatively low average levels of labour productivity in the British industry are associated with lower levels of shopfloor skills and knowledge as compared to certain other countries. For example, in comparisons between Britain and Germany and the Netherlands based on selected product areas in metal products and mechanical engineering, the larger proportions of production workers trained to craft level in the two Continental industries were found to contribute positively to productivity performance in several different ways, for example, through their greater ability (as compared to semi-skilled workers) to reach demanding quality standards under the daily pressure of small- and medium-batch production and to switch flexibly between different products and tasks (Daly, Hitchens, Wagner 1985; Mason and van Ark, 1996).

12. The wider impact of engineering skill deficiencies was shown in comparisons based on other industries in which industrial performance is heavily dependent on machinery being kept in good running order. In three different branches of manufacturing – kitchen furniture, clothing and food processing – the incidence of machinery malfunctioning and downtime was found to be substantially higher in Britain than in Germany. The higher rate of machine breakdown in British factories was associated with lower levels of engineering

[2] The *Skill Needs in Britain 1997* survey covered 4005 establishments with 25 or more employees in all business sectors (public and private) except for agriculture, forestry and fishing (IFF, 1998).

maintenance skills and also with lack of attention to preventative maintenance procedures by managers and supervisors (Steedman and Wagner, 1987; 1989; Mason, van Ark and Wagner, 1996).

13. Low levels of skill by international standards need not be fatal to the future competitiveness of firms in any country if this disadvantage is offset in various ways. For example, when the Anglo-Dutch engineering comparisons were extended to the United States where shopfloor skill levels are on average even lower than in Britain, it was found that US labour productivity levels were on average higher than in either Britain or the Netherlands. One of the main factors offsetting lower shopfloor skill levels in the US was economies of scale: US workers were generally not required to change between machines and products as often as their European counterparts and therefore did not need the same breadth of skills. At the same time the US industry has long benefited from a relatively large supply of graduate engineers who provide close support to and supervision of semi-skilled workers on the shopfloor (Mason and Finegold, 1997).

14. However, in the British case there is little scope for large-scale engineering production along traditional American lines – and indeed even in the US there are grounds for concern about growing competition from mass producers of standardised goods in lower-wage countries. In most branches of engineering the majority of European producers – in Britain as on the Continent – have long faced such competitive pressures to refocus production towards small- and medium-batch production of higher value added products. [3] Up till now the British industry has had the advantage of relatively low labour costs to offset its lower skills and labour productivity performance relative to Continental industries but there is no guarantee that this cost advantage can be sustained – and indeed in recent years it has proved vulnerable to exchange rate movements (EEF, 1998).

15. Hence, the international comparisons that have been carried out suggest that the British engineering industry does suffer from a 'latent' skills gap over and above the skills gap as currently perceived by employers. In many firms where existing skill levels appear to be adequate to meet present business objectives, it may be questionable whether the product and training strategies associated with those objectives are sustainable into the medium and long term. Future research in this area therefore needs to give detailed attention to the relationship between product strategies, skills and prospective changes in product markets.

[3] This assessment applies to many other UK industries besides engineering but not to all of them. The extent to which a product strategy based on low-skill, low value added production of standardised goods is a viable strategy into the foreseeable future is a matter for empirical investigation in each different industry. See Mason, van Ark, Wagner (1996) for further discussion of these issues.

## Cyclical and structural skill problems

### Periodic recurrence of recruitment difficulties

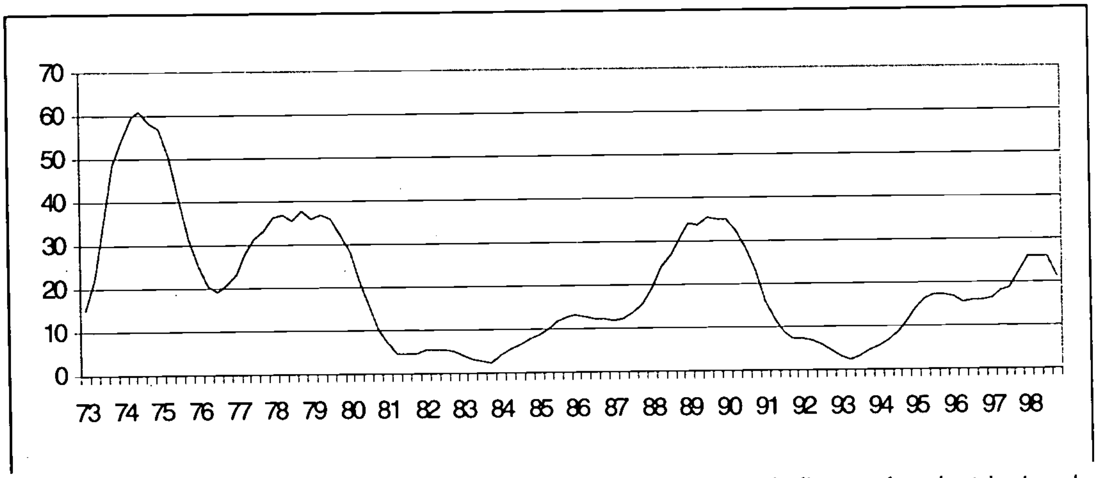
16. The cyclical nature of engineering recruitment difficulties over the last 25 years is clearly shown in Figure 1. In mechanical engineering the proportion of enterprises reporting skilled labour as a constraint on output in CBI surveys peaked about 9-12 percentage points lower in the first half of 1998 than previous peaks in 1978 and 1989. In electronic and electrical engineering the 1998 peak bore no comparison with that in the late 1980's and was still about 9 percentage points below the late 1970's peak.

**Figure 1 Recruitment difficulties in engineering industries, 1972-98**

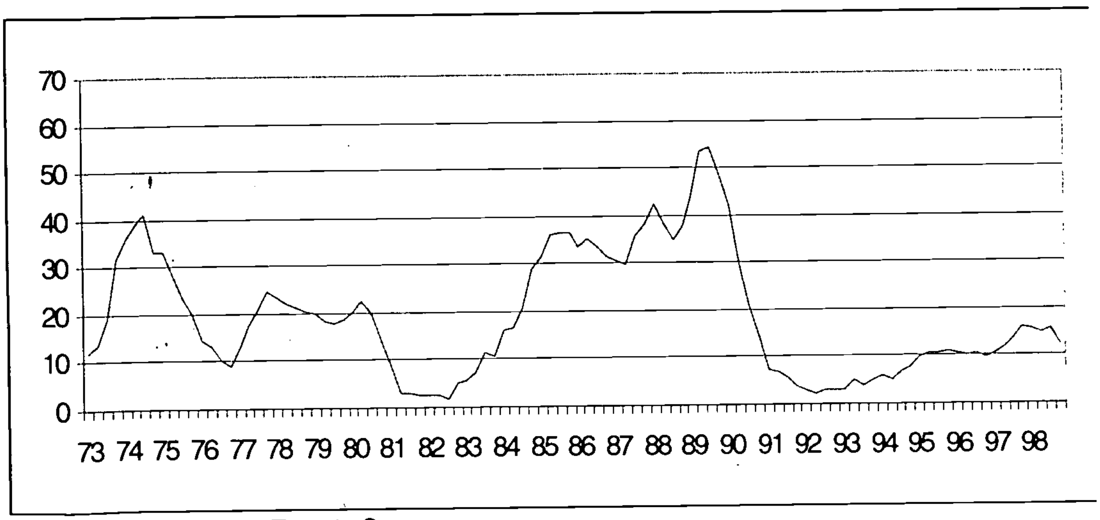
(four-quarter moving average of quarterly data)

*Percentage of respondents who answered 'yes' to the question: 'Is shortage of skilled labour likely to limit your output over the next four months?'*

(A) Mechanical engineering (prior to January 1978 mechanical engineering included manufacturers of scientific instruments)




(B) Electrical and electronic engineering (From April 1984 onwards figures for electrical and electronic engineering include instrument engineering companies as well)




Source: CBI Industrial Trends Survey

## Enterprise responses to recruitment difficulties

17. According to survey evidence during the 1980's, the main areas of engineering recruitment difficulty at the time were in professional engineering and craft occupations (CBI/MSC, 1986; Lewis and Armstrong, 1986; O'Farrell and Oakey, 1993). As Figure 1B shows, skilled labour shortages in electronic/electrical engineering in the late 1980's were even more serious than during the early 1970's boom period. Lewis and Armstrong (1986) noted a particular scarcity of software engineers and technicians in the mid-late 1980's along with evidence of demand exceeding the supply of people combining electronics and programming skills with other areas of engineering skill. Since then there has been considerable growth in the numbers of people qualifying at different levels in computer science and software engineering [4] and much employment-based training has covered the use of microelectronics-based equipment. [5] These developments may have helped to reduce the gap between supply and demand for software- and IT-related skills during the most recent economic upswing as compared with that in the late 1980's.

18. Although the reported level of recruitment difficulties at the business cycle peak in early 1998 was below that in previous decades in both mechanical and electronic/electrical engineering, it remains unclear to what extent this should be interpreted as an overall improvement in the economy's ability to meet engineering skill needs. A particular reason for concern in the case of high-level skills is that protracted recruitment difficulties are more likely to slow down the development of new products than restrict the output of existing products (Mason, 1999) and thus may not be captured by the CBI survey question.

19. The experience of the British engineering industry is that decisions taken by employers and individuals during each phase of the business cycle have a direct impact on the extent and nature of future skill problems. For example, during peak periods of recruitment difficulty, employers may respond to the problems in a variety of different ways. 'Positive' responses -- for example, providing additional training for existing staff or for new recruits whose skills and qualifications fall short of desired levels -- should help to alleviate recruitment difficulties in the future. However, there are a variety of other more short-term forms of response -- such as subcontracting out more work, purchasing the services of contract agency personnel or paying for additional overtime by existing staff -- which add to production costs without contributing to long-term solutions to skill shortfalls. And another category of response to

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[4] For example, First degree awards in mathematical and computing sciences almost doubled between 1988-96 while BTEC/SCOTVEC Higher National awards in this area rose by roughly a third (DfEE, *UK Education Statistics for the United Kingdom*, various issues)

[5] For example, training in the use and programming of CNC machine tools (often through courses provided by equipment vendors) and training in Statistical Process Control (SPC) techniques of quality control.

recruitment difficulties can only be described as 'negative' in nature, for example, turning away new orders, cutting back on production or taking no action of any kind. Negative actions of this kind can ultimately result in skill deficiencies 'curing themselves' in a perverse way insofar as the skills may no longer be required simply because the employers concerned have lost market share or gone out of business.

20. Recent survey evidence shows that, not surprisingly, the most common form of action taken by employers in the face of difficulties is to seek to expand and/or improve existing job advertising and recruitment activities. In the EMTA survey 40% of establishments experiencing recruitment difficulties cited 'increased recruitment efforts' as a form of response (Table 6), something which may be beneficial at the level of individual firms and may also have some positive effects on matches between employers and employees by increasing information flows in the labour market. Some 28% of establishments did cite various forms of training response or recruitment of less qualified staff who would presumably be in need of training. About one in five firms said that no action had been taken to deal with problems of hard-to-fill vacancies.

Table 6 Actions taken by engineering establishments as a result of experiencing recruitment difficulties

| | Percent of establishments with hard-to-fill vacancies |
|---|---|
| Increased recruitment efforts | 40 |
| Recruited less qualified, skilled or experienced staff | 13 |
| Retrained existing staff | 9 |
| Taken on apprentices/trainees | 6 |
| Increased overtime | 5 |
| Increased internal training (on-the-job etc) | 3 |
| Improved pay/conditions | 3 |
| Other responses | 11 |
| No action taken | 22 |

Source: EMTA (1998, Table 5.6)
Note: Respondents could cite more than one course of action

21. In the case of engineering and other technical graduates, Mason (1999) distinguishes between two different kinds of employer response to recruitment difficulties: firstly, efforts to minimise any commercial damage arising from the problem; and, secondly, actions taken to acquire the skills and knowledge in which employers are deficient. [6] The results presented in Table 7 show that, not surprisingly, firms' main efforts to reduce the commercial impact of graduate recruitment difficulties differed according to the level of commercial

[6] Although many firms naturally deploy several of these measures at the same time, the answers to the question posed give some idea of the order of priority involved.

damage which had been experienced. Only one in ten of respondents with commercial problems reported 'no specific action taken' compared to one in four without such problems. Within both groups of enterprises, more firms gave first priority to positive forms of action involving additional training costs or increased expenditure on recruitment and advertising than to short-term responses such as bringing in contract agency personnel or paying for higher levels of overtime. Comparison of unweighted and employment-weighted responses to this question suggests that large firms experiencing recruitment-related commercial problems were more likely than SME's to resort to the use of agency staff while large firms without immediate commercial problems were more likely to fill their gaps in graduate recruitment with less well-qualified people.

22. When employers facing graduate recruitment difficulties were asked to describe the single most important way in which they sought, not to minimise commercial losses resulting from the problem, but rather to improve their ability to recruit the types of graduate they required, the great majority of responses were positive in nature (Table 8). Only one in twenty such firms reported that no specific action had been taken. On this issue there were few differences in the pattern of such responses between firms reporting commercial damage arising from recruitment difficulties and those who did not. Rather, what stands out is the high priority given by large firms in particular to improving links with selected university departments ahead of raising salaries or deploying a wider range of recruitment methods. By contrast SME's reported a wider range of main responses, covering enhanced advertising/recruitment and salary increases as well as closer contacts with universities.

23. In common with the training-based initiatives cited by some firms as a means of substituting for graduate-level skills, all such responses to difficulties in recruiting engineering and other technical graduates should in principle help to reduce the incidence of future recruitment difficulties. This includes salary increases since, although they add to labour costs, in the long term -- all else being equal -- such increases should help to persuade more university students to enrol in the subjects in question). However, it has yet to be seen to what extent these positive forms of activity will be maintained as the incidence of graduate recruitment difficulty declines.

Table 7 Response to open question to employers reporting difficulties in recruiting engineering, science and/or IT graduates: What is the single most important way in which you try to minimise the effect of these particular graduate recruitment difficulties on your company?

| | Experiencing Commercial Problems | No commercial problems | Experiencing commercial problems | No commercial problems |
|---|---|---|---|---|
| | Percent of recruiters facing difficulties (unweighted) | | Percent of recruiters facing difficulties (employment-weighted) | |
| *Positive:* | | | | |
| Additional training for existing staff | 26 | 20 | 14 | 18 |
| Improve recruitment methods/advertise more widely | 21 | 10 | 12 | 17 |
| Offer jobs to less well-qualified personnel (a) | 9 | 13 | 14 | 34 |
| *Short-term:* | | | | |
| Use more contract agency staff or sub-contractors | 9 | 7 | 38 | 8 |
| Seek more overtime from existing staff | 3 | 3 | 4 | 0 |
| *Negative:* | | | | |
| Turn away orders/reduce workload | 5 | 0 | 4 | 0 |
| No specific action taken | 10 | 27 | 5 | 15 |
| Other responses | 14 | 17 | 7 | 4 |
| Don't know/refused | 3 | 3 | 1 | 4 |
| TOTAL | 100 | 100 | 100 | 100 |
| | *n = 77* | *n = 30* | *n = 77* | *n = 30* |
| SUMMARY: Percent of responses (b) | | | | |
| Positive | 67 | 54 | 44 | 75 |
| Short-term | 14 | 13 | 46 | 9 |
| Negative | 18 | 34 | 10 | 16 |
| TOTAL | 100 | 100 | 100 | 100 |

(a) Classified as 'positive' form of response on assumption that suitable training is provided for less well-qualified recruits.

(b) Excludes don't knows and responses classified to 'other' category.
**Source:** Mason (1999)

Table 8 Response to open question to employers reporting difficulties in recruiting engineering, science and/or IT graduates: What is the single most important way in which you try to improve your ability to recruit the types of graduate you require?

| | Experiencing commercial problems | No commercial problems | Experiencing commercial problems | No commercial problems |
|---|---|---|---|---|
| | Percent of recruiters facing difficulties (unweighted) | | Percent of recruiters facing difficulties (employment-weighted) | |
| Advertise more widely | 31 | 33 | 21 | 39 |
| Seek to develop closer links with university departments (a) | 28 | 20 | 59 | 55 |
| Increase salaries on offer to such graduates | 13 | 13 | 8 | 2 |
| Use wider range of recruitment methods | 12 | 13 | 6 | 2 |
| More structured training and development programme | 5 | 7 | 2 | 2 |
| Networking/links with other companies | 4 | 3 | 3 | 0 |
| Take on less qualified people and provide training | 1 | 0 | 0.5 | 0 |
| No specific action taken | 5 | 3 | 0.5 | 0 |
| Other responses | 1 | 0 | 0 | 0 |
| Don't know/refused | 0 | 7 | 0 | 1 |
| TOTAL | 100<br>*n = 77* | 100<br>*n = 30* | 100<br>*n = 77* | 100<br>*n = 30* |

(a): Includes requests to university departments to change existing courses or start new ones

Source: Mason (1999)

## Business recessions and engineering skill supplies

24. In the case of craft skills -- perhaps the single most important recurrent area of engineering recruitment difficulty over recent decades -- all available evidence suggests that it is employer actions during business recessions which have the most profound impact on the future supply of skills in later periods of economic expansion. Between 1980-83 annual recruitment of craft trainees in the engineering industry fell by 55%, over twice as fast as the fall

in total craft employment engendered by the deep recession of 1980-81 (EITB, 1987). Subsequently, in the economic recovery of the mid-late 1980's, craft trainee numbers (expressed as a proportion of craft employment) came nowhere near to regaining pre-1980 levels in spite of additional elements of government subsidy channelled through the Youth Training Scheme (YTS). Technician trainee numbers also fell through most of the 1980's although they represented a rising share of overall apprentice recruitment in engineering during this period (ibid).

25. Stevens (1994) finds that craft training levels throughout this period were negatively related to real interest rates (an indicator of the cost of undertaking any form of investment) and were also correlated with measures of difficulty in recruiting skilled labour on the external labour market. Another factor in the overall decline in craft training was the shutdown of some company-based training facilities during the early 1980's recession (EMTA, 1998) and the reluctance of large firms to continue their previous practice of training apprentices in excess of their own needs, something which had hitherto worked to the advantage of smaller employers (Hudson, 1998). [7]

26. The recurrence of craft recruitment difficulties in the late 1980's reflected several factors which were well recognised at the time. Many of the craft workers made redundant during the recession had found employment in other sectors of the economy or gone into self-employment. Others had retired or effectively withdrawn from the labour market following years of unemployment and deterioration of their skills (EITB, 1987). A similar process later unfolded once again in the early 1990's with more lay-offs of skilled engineering workers and another series of reductions in engineering apprentice intakes (Gospel, 1998) which contributed to a new period of recruitment difficulties towards the end of the present decade. Recent government-sponsored efforts to increase training have not been helped by shutdowns of some engineering departments in further education colleges or by the increased financial difficulties experienced by private training providers such as Group Training Associations (EMTA, 1998).

### Assessment: cyclical and structural skill problems

27. The main occupational areas in which recruitment difficulties periodically recur – craftspeople, technicians, graduate engineers -- are those which require relatively long periods of time for trainees or students to acquire the necessary skills and knowledge. During periods of recession there are strong cost pressures on employers to reduce expensive long-duration training programmes which, when aggregated across the whole industry, have severe and long-lasting consequences for the future availability of skilled labour in

[7] However, Knight and Latreille (1996) find that apprentice training levels in the early 1980's were still strongly positively related to firm size. Their results also imply that reduced voluntary turnover of skilled labour during the recession must have contributed to reduced intakes of new apprentice trainees.

the event of economic recovery. However, in periods of rapid growth and recruitment difficulty, the lead-times involved in craft and technician apprentice training are too long for the expansion of such training to help employers cope with immediate shortages of skilled labour.

28. In this context it is fair to argue that the long-run trends in training levels and recruitment difficulties which have been seen in the last three decades reflect structural rather than merely cyclical weaknesses in the British system of engineering training. Institutional arrangements and incentive structures governing training decisions in Britain have clearly not succeeded in encouraging employers to support long-duration engineering training consistently through each phase of the business cycle.

29. The experience of periodic recession may also have lasting effects on labour supply to the extent that the willingness of young people to seek training opportunities in engineering is reduced by negative advice from older generations about the insecurity attached to employment prospects in the industry. Similar considerations may also deter some prospective university students from electing to study engineering at degree level.

30. Other deficiencies in engineering training which may be described as structural in nature relate to short-duration training of one kind or another. In a study of the determinants of workplace training based on the Employers Manpower and Skills Practices Survey (EMSPS), Green, Machin and Wilkinson (1996) found that the intensity of continuing training in the metal goods, engineering and vehicle industry was significantly lower than in most other industries for three different occupational groups: management and administrative, clerical and secretarial and personal and protective service occupations. [8] The EMTA (1998) survey found that, even at the peak of recent external recruitment difficulties in early 1998, as many as 60% of engineering establishments still identified barriers to training of existing staff, in particular, the opportunity costs of releasing staff for training and the cost of training itself.

31. As Table 9A shows, some 39% of engineering establishments surveyed by EMTA had not offered any on-the-job training in the previous 12 months and another 27% had provided such training to no more than 25% of their workforce. As in other industries, training was positively related to establishment size. On larger sites (employing 250 or more people) one third of establishments provided on-the-job training for three quarters or more of their workforce but still another third had confined such training to a quarter of employees or fewer. In terms of continuing training for adult employees, about 45% of larger establishments had provided off-the-job training in the previous

[8] The intensity of training is here defined as the proportion of employees receiving training multiplied by the average number of days training received. I am grateful to David Wilkinson for the use of unpublished data from this study.

12 months to 25% or more of adult employees. However, half of all establishments (mostly the very small ones) had not offered any such training to any of their staff (Table 9B).

Table 9 Incidence of on-the-job and off-the-job training in EMTA sample of engineering establishments

A: Employees receiving on-the-job training in previous 12 months

| | Size of establishment, number of employees | | | |
|---|---|---|---|---|
| | 5-49 emp. | 50-249 emp. | 250+ emp. | TOTAL |
| | *Percentage of establishments* | | | |
| No on-the-job training given | 45 | 15 | 5 | 39 |
| % of workforce receiving training: | | | | |
| Under 25% | 25 | 38 | 27 | 27 |
| 25-49% | 9 | 11 | 17 | 10 |
| 50-74% | 6 | 13 | 17 | 7 |
| 75% or more | 15 | 22 | 33 | 17 |
| TOTAL | 100 | 100 | 100 | 100 |

B: Employees aged 25 or more receiving off-the-job training in previous 12 months

| | Size of establishment, number of employees | | | |
|---|---|---|---|---|
| | 5-49 emp. | 50-249 emp. | 250+ emp. | TOTAL |
| | *Percentage of establishments* | | | |
| No off-the-job training given | 57 | 19 | 7 | 50 |
| % of workforce receiving training: | | | | |
| Under 10% | 24 | 49 | 33 | 28 |
| 11-25% | 8 | 10 | 13 | 8 |
| 25-49% | 6 | 11 | 20 | 7 |
| 50-74% | 2 | 6 | 15 | 3 |
| 75% or more | 3 | 5 | 10 | 4 |
| TOTAL | 100 | 100 | 100 | 100 |

Source: Derived from EMTA, 1998 Labour Market Survey of the Engineering Industry in Britain, Tables 7.5 and 7.10.

## Engineering skills, new technology and work organisation

32. A particular reason for concern about sustained weakness in long-duration engineering training in Britain is that in many different ways the skill requirements of engineering employers appear to be rising over time. Indeed, periods of recession when cost pressures to cut back on training are at their highest are also likely to be periods when companies' internal skill gaps may widen due to increased competitive pressures in product markets.

33. One indicator of rising skill requirements is the changes over time in occupational structure which have taken place in the industry: in manufacturing engineering as a whole the shares of professional engineers and managers in total employment have steadily increased over the last 20 years while the employment shares of lower-skilled production operators and clerical staff have declined (EITB, 1989; EnTra, 1994). Data discontinuities make it difficult to establish what the long-term trends in craft and technician employment shares have been. As of 1993 they accounted for 19% and 8%, respectively, of total engineering employment (EnTra, 1994).

34. As is now widely agreed, the effects of technological change on workforce skill levels are likely to vary between individual enterprises according to management decision-making about product strategies and work organisation. In most branches of British engineering, managerial choices have been constrained by competition from mass producers of standardised goods in lower-wage countries which has applied gradual pressure over time to shift production towards small- and medium-batch production of more skill-intensive, higher value added products.

35. Such market pressures ensure that, even when in principle new technologies might permit some de-skilling to take place, there is little merit in defining this as an objective for most engineering firms. For example, O'Farrell and Oakey (1993) describe the many ways in which CNC (computer numerical controlled) equipment eases the tasks involved in setting-up machine tools. However, in their study of small UK engineering companies they found very little evidence of lower-skilled workers having been substituted for craft-trained workers to operate CNC machinery. In fact new skills were needed to programme and maintain the new equipment and to achieve full benefits from its flexibility. In addition, craft-skilled workers were still frequently called upon to set and operate conventional machine tools while CNC equipment was working smoothly. Lyons and Bailey (1993) found that, even in the case of small engineering subcontractors facing downward pressure on costs from large customers, access to flexible skilled labour was a more important consideration than having access to cheap labour.

36. The size of firms is relevant here in the light of long-running debates about the impact of CNC machinery on shopfloor skills depending on which category of workers was assigned the task of programming (Jones, 1982; Zicklin, 1987; Burnes, 1988). In many large American establishments full responsibility for CNC programming is taken by graduate engineers and other office-based staff and shopfloor operators are not permitted to edit or modify programmes (Kelley, 1990). However, in Britain and other European countries, recent evidence suggests that, while in large and medium-sized establishments CNC programming may often be done off the shopfloor by specialist (technician-level) programmers, shopfloor operators are usually free

(indeed often expected) to edit or modify programmes as required. In smaller plants (employing 100 people or less), full shopfloor programming is common, in part because of the growing user-friendliness of the equipment (Mason and Finegold, 1997).

37. As microelectronics-based equipment has diffused widely across the engineering industry, the old debates about programming have been superseded in many ways by the impact on skill requirements of increased competitive pressures in most product markets (for example, pressure to compete on price as well as on quality and delivery times) and of the changes in work organisation which firms have adopted in order to help them cope with this increased competition. In engineering, as in many other industries, moves towards cell-working, team-working and 'delayering' (flatter management structures) tend to require higher levels of task discretion and individual responsibility from all categories of employee except for the very lowest-skilled. The spread of 'high-involvement' work practices such as team-working also helps to explain why those engineering employers who identified skill gaps in their workforce put so much emphasis on deficiencies in personal, communication and problem-solving skills alongside the practical skills which are needed (Table 5).

38. In the area of high-level skills, Mason (1999) identifies changes in markets and work organisation as key factors which now cause engineering employers to have much higher expectations of graduates than were typically applied to earlier generations. For example, the growing need for technical staff to have more direct contacts with customers is an important reason why employers now place such emphasis on the communication and inter-personal skills required of engineering graduates. With the exception of electronic engineers (discussed below), most graduate engineering recruitment difficulties in 1998 were found to have far more to do with perceived shortcomings in the *quality* of graduates (for example, their lack of work experience and apparent weaknesses in communication skills) than any shortfall in their quantity (ibid).

## ENGINEERING EDUCATION AND TRAINING

### Intermediate skills formation

39. Over the last ten years or so the engineering industry, in common with the rest of the economy, has seen a large reduction in the number of employees who do not hold vocational qualifications of any kind (Table 10). Between 1988-98 the proportion of the engineering workforce holding vocational qualifications at craft (lower intermediate) level or above rose from 43% to 53%. In spite of the drop in craft trainee numbers in the early and mid-1990's (Section 3.3), the craft-qualified share of employment actually rose by two percentage points over the decade. However, this reflected the disproportionate share of job losses incurred by lower-skilled workers during

the early 1990's recession; in absolute terms the number of craft-skilled employees in the industry declined by some 12% over the same period.

40. In the two years to mid-1998 just over 16,000 engineering trainees were enrolled for Modern Apprenticeships (MA) in England, about 10% of total MA starts. As Table 11 shows, the engineering MA trainees were overwhelmingly male and also tended to be more concentrated in 16 and 17 year old age groups than was true for MA trainees as a whole. As in other industries, the MA in engineering is widely regarded as a more flexible version of traditional apprenticeships with fewer restrictions on the age of entrants and more possibilities of upward progression for trainees (for example, to higher education). However, concerns have been expressed about the relatively small numbers of trainees who are involved as well as about regional and local variation in funding arrangements and variability in standards (Gospel, 1998; EMTA, 1998; Steedman, Gospel and Ryan, 1998). Since MA training is based on the NVQ framework, it is also subject to the criticisms made of the NVQ emphasis on task performance at the possible expense of deeper knowledge and understanding of engineering principles (Senker, 1996; Fuller and Unwin, 1998).

41. As yet there appears to be no firm consensus as to whether the numbers entering MA's in engineering are constrained primarily by a lack of training places offered by employers or a lack of suitably qualified prospective trainees. This may be because of regional variations in the balance between supply of and demand for engineering training places (Gospel, 1998). Steedman, Gospel and Ryan (1998) suggest that MA trainee wages will need to decline (or government subsidies increase) to secure any large increase in the number of training places. They also stress the need for MA's to attract able young people who would otherwise consider studying full-time in higher education and for pre-apprenticeship courses in full-time education to be developed to prepare under-qualified 16 and 17 year olds for later entry to MA schemes. The latter objective could be served by EMTA's recent development of National Traineeships which will have two routes for 16-17 year olds, one broad-based allowing for progression to MA, the other designed to develop skills in specific occupations.

Table 10 Highest qualifications (a) held by workforce in metal goods, engineering and vehicles industries and in All Industries, 1988 and 1998

A: Metal goods, engineering and vehicle industries (1988: SIC (1980) Division 3; 1998: SIC (1992) Groups 28-35)

*Percentages*

| | 1988 | 1998 |
|---|---|---|
| Degree or above | 8.1 | 10.8 |
| Higher intermediate vocational | 6.6 | 11.3 |
| Lower intermediate vocational | 28.6 | 30.8 |
| *Sub-total: vocational qualifications at craft level or higher* | *(43.3)* | *(52.9)* |
| Basic vocational | 6.7 | 9.2 |
| A level or equivalent | 3.5 | 4.3 |
| O level or equivalent | 11.8 | 15.2 |
| No vocational qualifications or general qualifications higher than GCSE grade D or equivalent | 34.7 | 18.4 |
| TOTAL | 100 | 100 |

B: All Industries (All in employment (employees plus self-employed)

| | 1988 | 1998 |
|---|---|---|
| Degree or above | 9.0 | 15.9 |
| Higher intermediate vocational | 6.5 | 10.2 |
| Lower intermediate vocational | 17.4 | 19.3 |
| *Sub-total: vocational qualifications at craft level or higher* | *(32.9)* | *(45.4)* |
| Basic vocational | 7.0 | 10.7 |
| A level or equivalent | 6.1 | 7.6 |
| O level or equivalent | 17.9 | 19.0 |
| No vocational qualifications or general qualifications higher than GCSE grade D or equivalent | 36.2 | 17.3 |
| TOTAL | 100 | 100 |

Source: Labour Force Surveys
Percentages may not add up to 100 due to rounding

**Notes to Table 10:**

a. Classification of qualifications:

Graduate and above: All Higher and First degrees and professional qualifications of degree standard; plus NVQ level 5 in 1998; plus 5% of Other Qualifications.

Higher intermediate vocational: BTEC/SCOTVEC Higher National awards, sub-degree qualifications in teaching and nursing and equivalent awards; plus 5% of Other Qualifications. [1998 data include NVQ level 4].

Lower intermediate vocational: BTEC National awards, City & Guilds advanced craft and craft awards, completed trade apprenticeships and equivalent awards; plus 15% of Other Qualifications. [1998 data include NVQ level 3 and GNVQ Advanced awards]

Basic vocational: 1998: GNVQ Intermediate and Foundation awards; BTEC General and First awards; City & Guilds awards below craft level; SCOTVEC National Certificate modules; YT, YTP certificates and equivalent awards; plus 75% of Other Qualifications. 1988: 15% of all City & Guilds awards and BTEC / SCOTVEC Ordinary/General awards have been classified to this category on the basis of detailed information derived from later Labour Force Surveys. A level or equivalent: A level, A-S level, Scottish CSYS, Scottish Higher and equivalent awards level or equivalent: GCSE grade A-C, O level, CSE grade one and equivalent Scottish awards. Distribution of 'Other qualifications' category based on estimates reported in Employment Gazette, July 1992.

Table 11 Modern Apprenticeship starts in engineering and in All Industries, analysed by gender and age group, England, 1996-98

A: Total numbers starting Modern Apprenticeships in 1996/97 and 1997/98

| | |
|---|---|
| Engineering manufacturing | 14944 |
| Engineering construction | 390 |
| Marine engineering | 817 |
| TOTAL | 16151 |
| All industries | 159908 |
| Engineering as % of total | 10.1 |

B: MA starts analysed by gender and age group

*Percentages*

| | Engineering Manufacturing | ALL INDUSTRIES |
|---|---|---|
| Male | 95.8 | 53.1 |
| Female | 4.2 | 46.9 |
| Age on entry: | | |
| 16 | 33.5 | 18.1 |
| 17 | 24.5 | 18.5 |
| 18 | 18.9 | 18.2 |
| 19 | 11.3 | 12.8 |
| 20-plus | 11.9 | 32.5 |

Source: DfEE, MA trainee database (31.7.98)

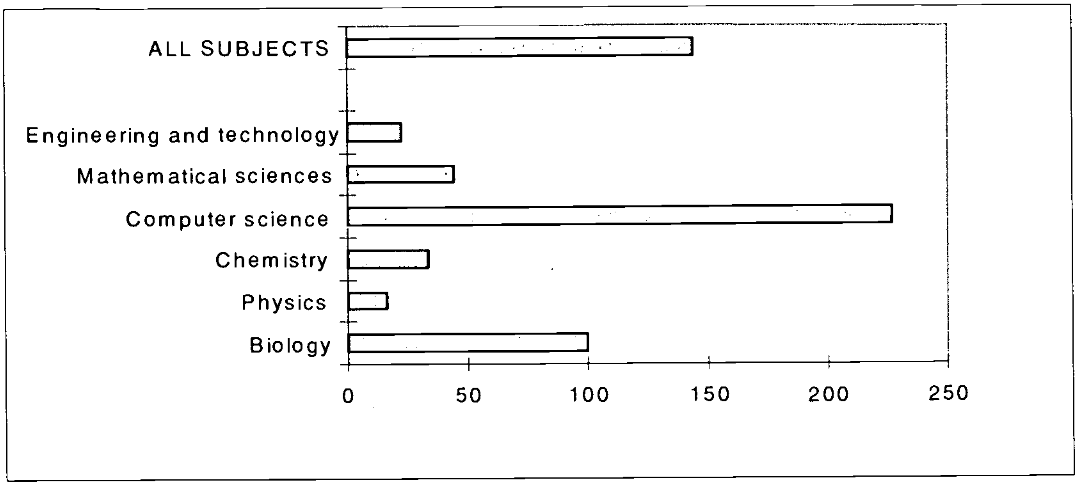
42. According to the Engineering Council (1998), data limitations make it impossible to develop a reliable time series for engineering enrolments and awards in Further Education (FE) colleges in recent years. In most colleges initial engineering education and training is provided through the NVQ(2F) programme. Enrolments on engineering GNVQ courses remain fairly small and EdExcel-BTEC reports that enrolments for National Diplomas/Certificates in engineering are now about six times larger than enrolments for GNVQ's. However, growth at lower levels of FE has not fed through to technician-level qualifications. In 1997-98 registrations for Higher National Certificates/Diplomas in engineering were 21% lower than four years previously. Furthermore, many of those taking Higher National qualifications go on to study for First degrees rather than seek employment as technicians (Engineering Council, 1998).

## Engineering graduate output

43. Engineering has shared in the expansion of UK higher education which began in the late 1980's but its rate of growth has been well below the average for

All Subjects and even further behind the growth in computer science/IT (Figure 2).

Figure 2 Percentage growth in home admissions to First degree courses in technical subjects and in All Subjects, UK universities, 1987-97




Sources:
1997: http://ucasweb.ucas.co.uk.higher
Universities and Colleges Admissions Service (UCAS), Annual Report 1997 Entry.
1987: Universities Central Council on Admissions (UCCA), Annual Report, 1986-87; Polytechnics Central Admissions System (PCAS), Annual Report, 1986-87.
Notes:
Computer science includes computer systems engineering, software engineering and artificial intelligence as well as computer science.
Mathematical sciences comprise mathematics, statistics and other mathematical sciences not listed under computer science.

44. As noted in Section 4, most graduate engineering recruitment difficulties in 1998 were found to have far more to do with perceived shortcomings in the *quality* of graduates than any shortfall in their quantity. The exception was in electronic engineering where recruitment difficulties do appear to have a quantitative as well as qualitative basis. Indeed, data on both student admissions and graduate output show that – after allowing for the reduction in numbers of students enrolled for 'straight' electrical engineering courses -- total student numbers in the combined group of electronic, electrical and combined electronic/electrical engineering have actually fallen during a period in which overall participation rates in higher education have more than doubled (Mason, 1999). The main reasons for this appear to be the opposing attractions of degree courses in computing/IT subjects and the limited Numbers of young people leaving school with qualifications in both maths and physics. [9]

[9] The Engineering Council (1998, Table 2.5) notes that GCE A level awards in physics declined by 13% between 1993-97, only part of which might be explicable by the fall in size of the 18 year old age group over this period.

45. Discussion about the quality of engineering graduates frequently centres on perceived weaknesses in the entry qualifications of university students in engineering as compared to new entrants in many other subject areas. Table 12 shows that roughly two thirds of home students admitted to engineering degree courses in a recent year held A levels or Scottish Higher qualifications, a higher proportion than in computer science or business studies but below that in all other main subject areas. Of the A level entrants in engineering, about 26% had gained 26 or more A level points, below the equivalent proportions in maths, languages and humanities but much the same as in biological and physical sciences and in social studies and considerably higher than in computer science or business studies. However, further scrutiny of A level score distributions gives some cause for concern about the academic ability of some of the 'weaker' A level entrants to engineering. Almost a third of engineering entrants with A levels in 1997 had scores of 15 points or less, compared with 20% or thereabouts in law and other subject groups such as languages and humanities (Mason, 1999).

46. Previous studies of engineering entry qualifications suggest that students with relatively low A level entry grades are clustered in about a third of higher education institutions which would not be able to fill their courses without relaxing their entry criteria (Barry, et al, 1997; Smithers and Robinson, 1996). In response to such concerns the Engineering Council has recently introduced minimum entry requirements for university courses seeking accreditation as part of the educational base for registration of Chartered Engineers. The stated aim of specifying entry standards in this way is 'to ensure a cohort of sufficient intellectual capability to support a high standard of course content' (Engineering Council, 1998: 39).

47. Since the proportion of engineering degree course entrants with vocational and other non-A level qualifications is relatively high (Table 12), university departments in this area have to cope with greater variability in students' academic backgrounds than most other subject areas (although not so wide a variation as is found among computer science students). Many of the non-traditional university entrants may have previously unfulfilled academic potential and in principle one might expect them to be well-endowed with the maturity, practical experience and inter-personal skills which employers are seeking. However, given the difficulties that universities face in meeting the needs of a more diverse student intake during a period of sharp resource constraints, it is possible that increasing variability in the academic backgrounds of university entrants is contributing to widening variation in the quality of engineering graduate output. [10]

[10] See Mason, 1999, Section 8, for further discussion of these issues.

Table 12 Entry qualifications held by UK-domiciled students admitted to First degree courses in UK higher education institutions, analysed by subject, 1997

| | Entry qualifications (percentages): | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total number of admissions | A levels or Scottish Highers | BTEC/ SCOTVEC | GNVQ | Access/ Foundation | Other (b) | None | TOTAL | *% A level entrants with 26 points or more* |
| Engineering & technology | 17001 | 66.4 | 12.6 | 3.3 | 2.3 | 6.5 | 8.9 | 100 | *25.6* |
| Biological sciences | 16840 | 81.7 | 3.0 | 1.9 | 6.1 | 4.2 | 3.0 | 100 | *24.9* |
| Physical sciences | 14732 | 85.4 | 2.5 | 1.2 | 3.1 | 3.6 | 4.1 | 100 | *25.4* |
| Computer science (c) | 12383 | 55.5 | 15.1 | 9.4 | 5.5 | 6.0 | 8.4 | 100 | *13.0* |
| Mathematical sciences (d) | 5621 | 87.3 | 2.2 | 0.9 | 1.9 | 4.1 | 3.7 | 100 | *44.1* |
| Social studies | 35198 | 72.6 | 4.1 | 3.5 | 9.1 | 5.5 | 5.2 | 100 | *25.2* |
| Business and administrative studies | 28180 | 62.3 | 10.7 | 14.2 | 2.4 | 3.9 | 6.5 | 100 | *11.7* |
| Languages and related disciplines | 17837 | 86.8 | 0.9 | 0.4 | 4.5 | 4.6 | 2.8 | 100 | *37.1* |
| Humanities | 10645 | 81.9 | 1.6 | 0.5 | 7.3 | 5.0 | 3.7 | 100 | *31.9* |
| ALL SUBJECTS | 276503 | 70.2 | 7.9 | 5.0 | 6.4 | 5.3 | 5.3 | 100 | *23.5* |

Sources:
1997: http://ucasweb.ucas.co.uk.higher
Universities and Colleges Admissions Service (UCAS), Annual Report 1997 Entry.
(a) Refers to candidates with two or more A level passes or equivalent
(b) Includes previous degree or partial degree credits and Baccalaureate qualifications
(c) Comprises computer science, computer systems engineering, software engineering and artificial intelligence.
(d) Comprises mathematics, statistics and other mathematical sciences not listed under computer science.

48. Since the proportion of engineering degree course entrants with vocational and other non-A level qualifications is relatively high (Table 12), university departments in this area have to cope with greater variability in students' academic backgrounds than most other subject areas (although not so wide a variation as is found among computer science students). Many of the non-traditional university entrants may have previously unfulfilled academic potential and in principle one might expect them to be well-endowed with the maturity, practical experience and inter-personal skills which employers are seeking. However, given the difficulties that universities face in meeting the

needs of a more diverse student intake during a period of sharp resource constraints, it is possible that increasing variability in the academic backgrounds of university entrants is contributing to widening variation in the quality of engineering graduate output. [11]

49. Other concerns about engineering graduate quality arise from complaints among traditional engineering employers that the 'best' graduates in engineering are frequently 'lost' to the financial services and other high-paying industries. Recent analysis of the labour market for technical graduates confirms that manufacturing engineering employers are poorly placed to compete with the graduate salaries offered in many service industries, and indeed in a typical recent year non-manufacturing sectors absorbed almost two thirds of new graduates in electronic engineering and just under half of new mechanical and production engineers (Mason, 1999). However, although an unknown proportion of these graduates may not make direct use of their engineering education, in general the widespread dispersion of highly-qualified engineers has some positive implications for the wider economy. Firstly, it helps to meet the demand for engineering skills and knowledge to install, manage and maintain complex machinery and equipment in use in sectors other than manufacturing engineering. Secondly, it encourages the gradual diffusion of technically-educated people into the ranks of senior management in a wide range of industries. [12]

### The mix of graduate and intermediate-level engineering skills

50. At present many British employers welcome the expanded supply of engineering graduates, partly because of increased demand for high-level skills and partly because those graduates have been educated primarily at individual and state expense. The rise in HE participation has in any event contributed to a decline in size of previous target groups for higher intermediate skills training (e.g. A level school leavers seeking employment). However, the resulting mix of high-level and intermediate skills does not entirely conform with skill requirements in many workplaces as witnessed by employer concerns about some graduates' lack of work experience, commercial understanding and communication and inter-personal skills.

51. Within the university sector much effort now goes into organising sandwich courses which address these concerns by building substantial periods of work experience into degree studies. In addition, many engineering departments have now devised alternative methods of developing practical

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[11] See Mason, 1999, Section 8, for further discussion of these issues.

[12] Contrary to widespread belief that British manufacturing companies are largely run by accountants, Barry et al (1997) found that highly-qualified engineers and scientists outnumbered accountants by three-to-one among top executives in manufacturing. Furthermore, Broadberry and Wagner (1996) note that roughly a quarter of new entrants to the Institute of Chartered Accountants in a recent year had degrees in engineering or science subjects.

experience and commercial understanding in undergraduate students -- for example, industry-based project work -- and are working with employers to try and 'get the balance right' between subject teaching and the further development of training in problem-solving, team-working and other generic skills as a means of preparing students for the pressures and demands of their future workplaces. Such efforts to substitute for the lack of work experience inherent in full-time university study can be seen as indirectly seeking to recreate key components of employment-based intermediate skills training which has declined with the development of mass higher education.

**Summary and assessment**

52. Engineering skill problems are most apparent when they manifest themselves in the form of external recruitment difficulties at the peak of each business cycle. The main occupational areas in which such difficulties periodically recur – craftspeople, technicians, graduate engineers -- are those which require relatively long periods of time for trainees or students to acquire the necessary skills and knowledge. During periods of recession there are strong cost pressures on employers to reduce expensive long-duration training programmes which, when aggregated across the whole industry, have severe and long-lasting consequences for the future availability of skilled labour in the event of economic recovery. However, in periods of rapid growth and recruitment difficulty, the lead-times involved in craft and technician apprentice training are too long for the expansion of such training to help employers cope with immediate shortages of skilled labour.

53. In this context it is fair to argue that the long-run trends in training levels and recruitment difficulties which have been seen in the last three decades reflect structural rather than merely cyclical weaknesses in the British system of engineering training. Institutional arrangements and incentive structures governing training decisions in Britain have clearly not succeeded in encouraging employers to support long-duration engineering training consistently through each phase of the business cycle. Other deficiencies in engineering training which may be described as structural in nature relate to short-duration training of one kind or another in small and medium-sized firms. These firms are frequently deterred from offering training to adult employees by the opportunity costs of releasing staff for training and the cost of training itself.

54. Given these problems, it is perhaps surprising that only a third of engineering establishments report that there is a gap between the current skills of their workforce and the skills required to meet business objectives. International comparisons of matched samples of engineering establishments suggest that a proportion of British engineering firms may conceivably be subject to

'concealed' or 'latent' skills gaps which cannot be identified through the standard survey questions which address this topic.

55. Apart from periodic difficulties in recruiting skilled craftspeople, technicians and professional engineers, the main areas of reported deficiency in skills and knowledge embrace a wide range of practical skills (defined as 'ability to carry out job-related tasks') and deficiencies in generic skill areas such as computer literacy, communication skills, problem-solving skills and 'personal skills' (such as 'motivation, ability to fit in'). The emphasis on communication and inter-personal skills reflects increased competitive pressures in most product markets (for example, pressure to compete on price as well as on quality and delivery times) and the changes in work organisation which firms have adopted in order to help them cope with this increased competition. In engineering, as in many other industries, moves towards cell-working, team-working and 'delayering' (flatter management structures) tend to require higher levels of task discretion and individual responsibility from all categories of employee except for the very lowest-skilled.

56. In the area of high-level skills, changes in markets and work organisation now cause engineering employers to have much higher expectations of graduates than were typically applied to earlier generations. For example, the growing need for technical staff to have more direct contacts with customers is an important reason why high levels of communication and inter-personal skills are now required of engineering graduates. With the exception of electronic engineering graduates – where output has scarcely risen in the last ten years -- most graduate engineering recruitment difficulties in 1998 were found to have far more to do with perceived shortcomings in the *quality* of graduates (for example, their lack of work experience and apparent weaknesses in communication skills) than any shortfall in their quantity.

57. At all levels of skill and knowledge, the mix of competencies required are most likely to be provided by courses of education and training which combine work experience and employment-based training with classroom study in an integrated way. At intermediate level this has traditionally been done through apprenticeship models of education and training and the Modern Apprenticeship (MA) in engineering now offers a relatively flexible version of this kind of skills formation. However, the numbers of trainees involved are still relatively small and there are concerns also about regional and local variation in funding arrangements and variability in standards.

58. One way to expand MA numbers would be to develop pre-apprenticeship courses in full-time education to prepare under-qualified 16 and 17 year olds for later entry to MA schemes. The latter objective could be served by the recent development of National Traineeships in engineering which will have two routes for 16-17 year olds, one broad-based allowing for progression to MA, the other designed to develop skills in specific occupations. However, all

such initiatives are likely to be limited in scale unless ways are found to alter the present balance of incentives and disincentives which condition employers' decisions about investing in training.

59. Furthermore, in the case of MA's, there appears to be no firm consensus as yet as to whether the numbers enrolled in engineering are constrained primarily by a lack of training places offered by employers or a lack of suitably qualified prospective trainees. More research is needed in this area to inform policy design. Much attention is given to young people's negative perceptions of engineering which deter many of them from seeking careers in this area. However, this may be a second-order problem relative to the cost barriers which deter many employers from offering training in the first place or problems in maths and science education in schools which restrict the numbers of young people who are even qualified to consider careers in engineering.

60. At higher technician and graduate levels, policy-makers are confronted with high rates of staying-on in full-time education by young people together as well as continued employer resistance to the costs of employment-based training. One way to expand the supply of people combining technical skills and knowledge with the generic skills which are best gained through work experience would be to develop new models of integrated education and training provision. For example, more full-time sub-degree courses could be developed in close liaison with employers with the prospect of full-time employment and accelerated on-the-job training being offered to students completing the course. (In this model, too, employers might later be encouraged to provide financial support for the employees concerned to study part-time to degree level). To motivate much larger numbers of educational institutions and employers to develop co-operative arrangements with each other, various instruments of government policy would need to be deployed (for example, conditional funding for further/higher education institutions and tax-based incentives for employers).

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