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Engineering Education in the United Kingdom: Standards, Quality Assurance and Accreditation*

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In recent years, the number of UK universities has greatly increased, as have the numbers of students. However, the concept of a university as a 'community of scholars' – involving teachers and pupils – still holds good. The scope and method of government funding is outlined, together with its link to the Quality Assurance Agency, responsible for the quality assessment of all subjects in all universities. The role of the Engineering Council and of the UK Engineering Institutions is described, especially in the accreditation of engineering degrees. Fresh national and international developments have led to the decision to raise the standards of UK engineering qualifications for those registering as Chartered Engineer (CEng) or Incorporated Engineer (IEng). These changes are included in the latest edition of the Engineering Council's publication 'Standards and Routes to Registration' (SARTOR), including the lengthening of the educational base by one year. The 'Matching Section' is introduced, enabling some students to take a shorter degree course followed by validated postgraduate learning. The participation of the UK in multi-national agreements on mutual recognition of qualifications is recorded. Of particular note are FEANI's 'European Engineer' (EurIng) title and the 'Washington Accord', comprising the mutual recognition of accredited degrees in eight countries. Benefits and barriers of such agreements are discussed.

THE UK UNIVERSITY SYSTEM

THE NAME 'University' derives from the Latin 'Universitas' which is a shortening adopted about AD 1400 of the full name 'Universitas Magistorum et Scholarium' – meaning the whole body of teachers and pupils.

Ever since Roger Bacon drew scholars from all over Europe to Oxford in the thirteenth century, British universities have held to this idea of a 'community of scholars' – a group of people, including pupils as well as teachers, pursuing together the higher branches of learning.

Oxford University came into being in the twelfth century and Cambridge University in 1209 as a result of the migration of scholars from Oxford. In Scotland, three of the four ancient Universities, St Andrews, Glasgow and Aberdeen, were founded in the fifteenth century, followed by Edinburgh in 1582.

University College, the original London University, opened in 1826 and marked a new phase because, for the first time, there were no race, religion or gender restrictions in its foundation. Subsequently, in the late nineteenth and early twentieth centuries, similar universities were established in about 20 of the larger cities. By 1939 there were a total of about 50,000 students. The most recent expansion in the number of UK universities occurred in 1991, when about 50 polytechnics, which already ran degree as well as sub-degree courses, were elevated to universities so, at a stroke, doubling the number. Today there are some 1 million UK university students, plus many from other countries. The increase in first-year numbers during the past decade is shown in Fig. 1, the 1997 figure corresponding to about 38% of the 18-year old population.

Figure 2 summarises the main features of UK universities. By and large, they continue to adhere to the 'community of scholars' concept, though this is coming under strain due to increasing financial pressures.

All UK universities (except one, Buckingham) are state funded. The money from government is channelled through the independent Higher Education Funding Council for England and Wales (HEFCE) and a similar body for Scotland. The task of these Funding Councils is to distribute about £8bn annually among the 100 or so universities according to the quantity and quality of their teaching and research activities. In addition to the government allocation, universities attract an additional £3bn or £4bn from research contracts and collaborative ventures with industry and commerce.

Until last year, students with homes in the UK paid no tuition fees, but £1,000 per year is now charged, though students coming from poorer homes pay a smaller amount. Loans at low interest are available to students, repayable over a period after graduation.

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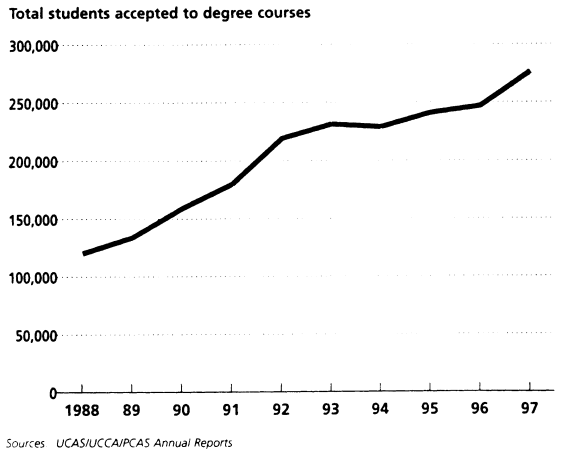

Fig. 1. Total students admitted to first year of degree courses (all subjects – students with homes in the UK only).

QUALITY ASSURANCE – ALL SUBJECTS, ALL UNIVERSITIES

In recent years the distribution of government money for higher education has increasingly been linked to the perceived quality of teaching and research in each university. For this purpose HEFCE has established the Quality Assurance Agency (QAA), whose task is to assess performance against a range of criteria. This formal evaluation system is a programme for assessing the quality of education in each department of every university in the country and will take eight years to complete.

For the assessment of teaching, a group of subjects is announced every two years and all departments in that group are visited by an academic team of specialist subject assessors. Between 1996 and 1998, for example, all departments of Electrical Engineering, Civil Engineering and Manufacturing Engineering were visited. The system operates well, although it does disrupt the work of the department for quite a long period before the assessment visit, as well as during the actual four days of the visit. All outstanding assessment visits will be completed by 2001. Some academics object to the scheme as an unwarranted interference in their work, but the general feeling is that a great deal of public money is allocated to the universities and it is not unreasonable to check that it is being well spent.

The teaching assessment procedure carried out by QAA involves measuring each department against its own objectives, using the framework shown in Appendix 1 [1] with the following six features of provision.

1. Curriculum: design, content, organisation.
2. Teaching, learning and assessment.
3. Student progression and achievement.
4. Student support and guidance.
5. Learning resources.
6. Quality assurance and enhancement.

The QAA grades each of these six features on a four-point scale, the lowest being 1 denoting unsatisfactory and the highest, 4, denoting that the aims and objectives are fully met. The maximum score is therefore 24. A mark of 20 is considered creditable.

The separate Research Assessment exercise of QAA is a quite complex operation in which each department's publications and facilities are evaluated on a scale from '1' (no significant research) to '5 star' (outstanding research of international importance). Government funding in each university department is closely determined by the results of the QAA exercise.

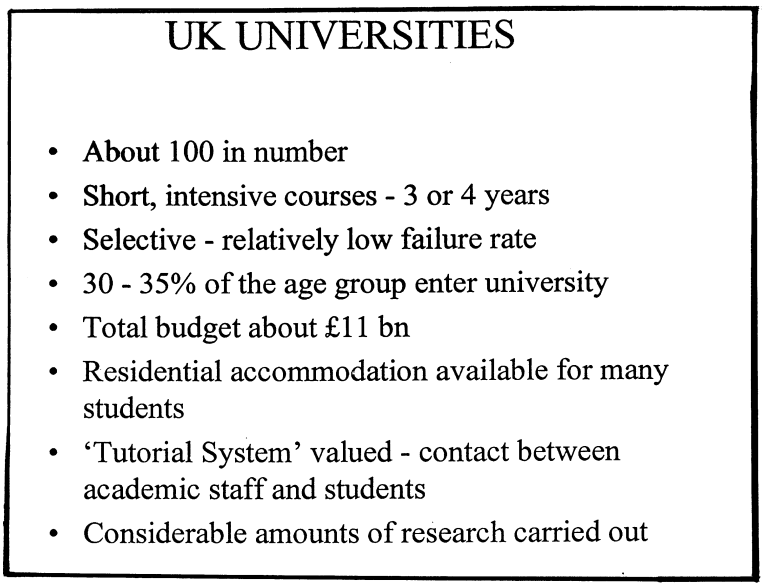

Fig. 2. Main characteristics of UK universities.

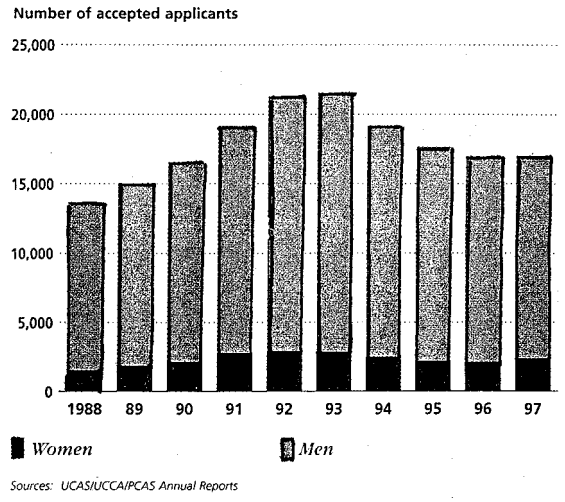

Fig. 3. Total students admitted to first year of engineering degrees (students with homes in the UK only).

UNIVERSITY ENGINEERING DEPARTMENTS

Engineering degree courses are available in the great majority of UK universities and account for about 8% of total university expenditure. Figure 3 shows the total entry to the first year of engineering degree courses over the past few years, while Table 1 gives the 1997 numbers entering in each of the engineering disciplines. As the failure rate is relatively low, these figures are also the approximate numbers of graduates. The figures are for UK students only and many others come from overseas.

THE ENGINEERING COUNCIL AND THE ENGINEERING INSTITUTIONS

The Engineering Council is a non-governmental organisation, run by the engineering profession, which acts as an 'umbrella body' for the UK engineering institutions. Its purpose is particularly to ensure that the voice of the profession is heard nationally and to act as a catalyst for inter-Institution activities. A central duty of the Engineering Council is to set standards of engineering education and training and to maintain the official UK Register for :

- Chartered Engineers (CEng)
- Incorporated Engineers (IEng)
- Engineering Technicians (EngTech).

Brief definitions of the qualities represented by these titles are given in Appendix 2.

The standards required for registration are published in the Engineering Council's policy statement 'Standards and Routes to Registration', known by the acronym SARTOR [2].

To qualify for CEng or IEng a candidate has to satisfactorily complete:

- an educational base – usually through an accredited degree course;
- validated initial professional development (IPD), comprising training and experience of a responsible nature;
- a professional review including an interview.

SARTOR is supported by a comprehensive Code of Practice which defines procedures for the accreditation of academic courses, training programmes and arrangements for experience.

Thirty-seven engineering institutions are recognised by the Engineering Council. They are allowed to determine if individuals have satisfied the education, training and experience requirements for registration and they may be licensed for the accreditation of academic courses and the arrangements for initial professional development. These institutions also carry out the professional review for each candidate, all their operations being subject to a checking procedure by the Engineering Council.

THE LATEST STANDARDS

Accreditation of degree courses in the UK commenced in the early 1960s. The latest edition of SARTOR was published in 1997 and raises standards significantly for the registration of CEngs and IEngs.

During the 1990s profound changes have occurred in the UK university system, with student numbers rising to record levels. Nowadays more than 30% of each age group enters higher education, compared with 15% a decade ago. The target, given in a recent government committee report [3] is a 45% participation rate.

In engineering, the needs of students, and consequently of degree courses, have been transformed by a number of circumstances, including:

- recognition that we are now operating in a global market for goods and services;
- the changed character of our universities, now that the UK is moving to a mass system of

Table 1. Students entering first year of Engineering and Computing degree courses (1997, students with homes in the UK only)

General	Civil	Mechanical	Aeronautical	Electrical	Electronic
2,278	1,925	3,298	986	119	2,651
Manufacturing	**Chemical**	**Other and Combinations**	**Total Engineering**		**Computer Science**
1,242	956	3,546	17,001		12,383

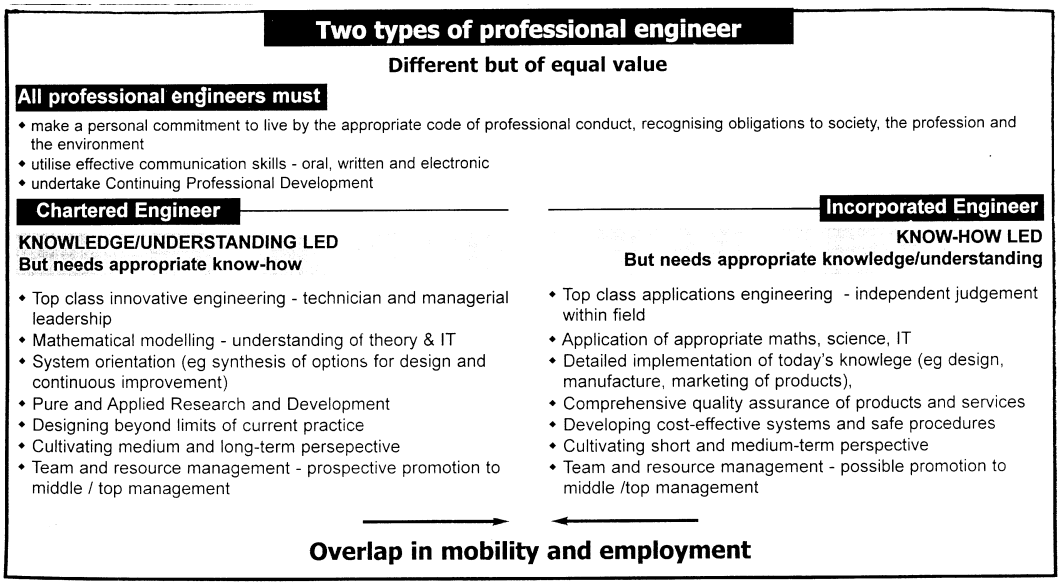

Fig. 4. Comparison of Chartered Engineers and Incorporated Engineers.

higher education and the consequent need for a broader range of courses;
- the increasing use of 'occupational standards' to describe employers' needs.

This new national and international situation has forced a revision of SARTOR to enable UK engineers to meet the needs of employers and maintain comparability with the best in the world. An additional factor underlining the need for change in engineering education is the perception that in UK university engineering departments there are a large number of students on courses accredited for Chartered Engineer who, it is believed, would benefit more from the Incorporated Engineer (i.e. Technology) type of course.

Briefly, the difference is that courses for Chartered Engineer are 'knowledge led' and research orientated towards tomorrow's technology, while Incorporated Engineer degrees are 'know-how led', aiming to produce experts in to-day's technology and its development. The differences are depicted in Fig. 4, and the exemplifying routes in Figs. 5 and 6.

The main changes made in the 1997 edition of SARTOR, which comes into force in 1999, are:

- For the Chartered Engineer, four years' degree study instead of the present three as the educational base.
- For the Incorporated Engineer, three years' study instead of the present two as the educational base.
- Minimum entry standards for degree courses accredited for Chartered Engineer or Incorporated Engineer.
- The adoption of a new concept, that of the 'Matching Section' (see below) for the completion of the educational base.
- The enhanced requirements in the educational base are complemented by improvements in the new second stage of formation, Initial Professional Development. IPD comprises the acquisition and development of the skills, specialist knowledge and competence needed to practise in a specific area of engineering;
- The competence achieved through IPD is to be demonstrated and assessed in a more stringent Professional Review process which is the final step before registration. The Professional Review requires a written report from the candidate and an in-depth interview by two Chartered or Incorporated Engineers.

THE EDUCATIONAL BASE

Figures 5 and 6 show respectively main pathways for the CEng and IEng qualifications. Those students heading for CEng take (preferably) a four-year degree leading to MEng or a three-year BEng degree, to which must be added a postgraduate year called a 'Matching Section' – described later.

Similarly, IEng candidates can take a three-year degree or a two-year qualification, plus a one-year Matching Section.

The MEng degree

The MEng degree is a broad-based four-year full-time first-degree programme (or equivalent sandwich or part-time). It is intended for students with high entry qualifications and motivation, providing an integrated programme of mathematically based foundation and specialist learning in a quality environment. It is supported by information technology and delivered against a business background, preferably international.

Within this basic specification, the content of MEng courses will vary with the discipline to meet

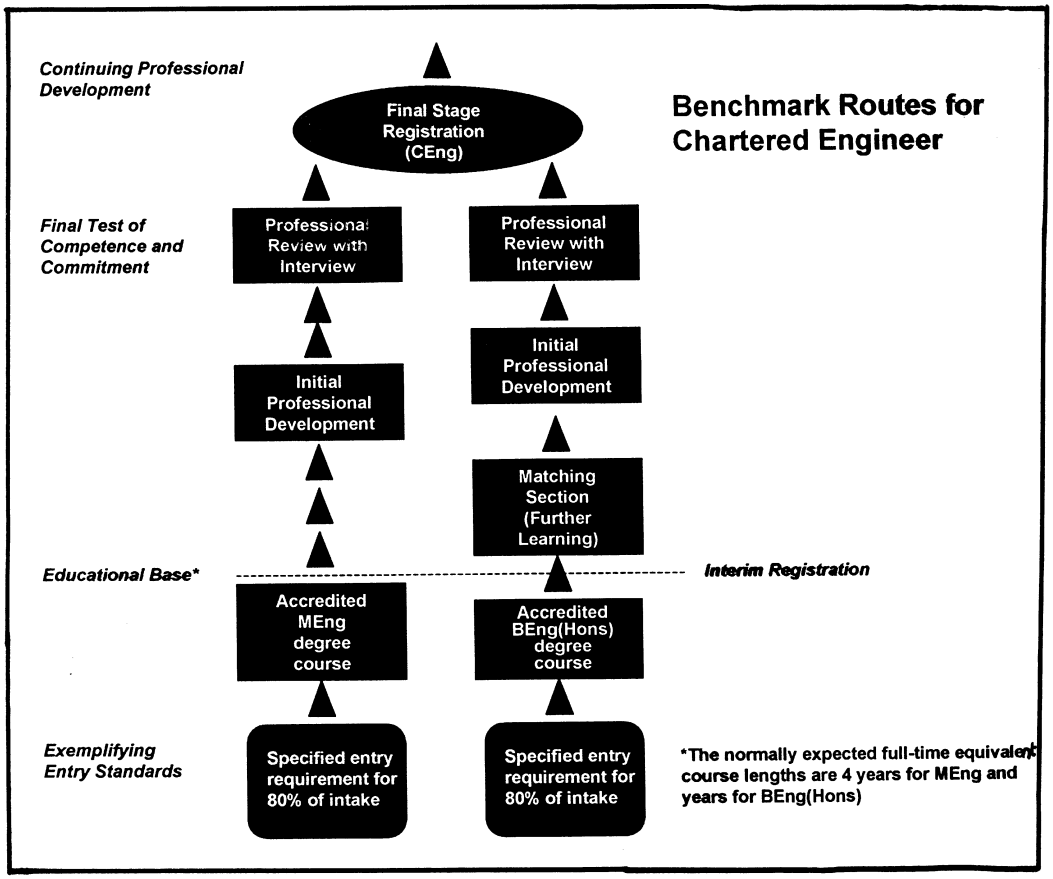

Fig. 5. Main pathways for Chartered Engineers.

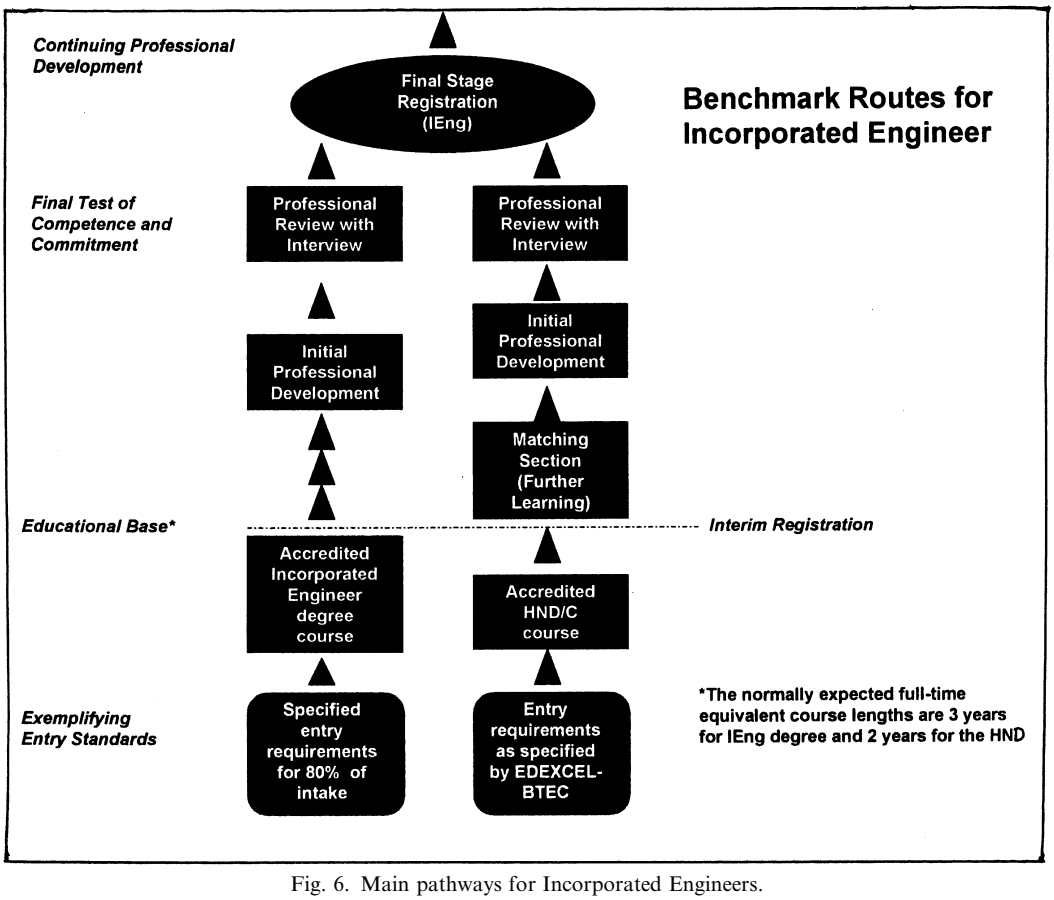

Fig. 6. Main pathways for Incorporated Engineers.

the needs of different industrial sectors and employers. Some will emphasise study of a particular branch of engineering to greater depth and breadth, some a multidisciplinary education in a range of engineering disciplines, some a command of business matters and practices, including elements of finance, marketing, costing and management – but safeguarding a recognised minimum of engineering science and technology. The course must be taught in the context of design, which provides an integrating theme. There must be industrial involvement in the framing and delivery of MEng courses.

It is important to emphasise the difference between MEng undergraduate and one-year taught post-graduate M.Sc. courses. While most M.Sc. courses involve in-depth study of a specialised area, the MEng is intended as a broader integrated course, advancing the student's knowledge, understanding and skills in a number of related areas. M.Sc. and MEng do not therefore duplicate one another and are not mutually exclusive. An M.Sc. course may, however, constitute a Matching Section.

The Incorporated Engineer degree

The IEng degree is a three-year full-time programme (or equivalent sandwich or part-time). The aim of accredited IEng degree courses is to develop the skills and attributes which Incorporated Engineers will be expected to display throughout their careers (Fig. 4). The subjects to be studied will vary according to the field of engineering, but all should be taught with an applications bias and in the context of design.

Consequently, a degree designed for accreditation against the IEng requirement should cultivate:

- high level technical proficiency in a major field of engineering, including the ability to tackle a variety of practical problems, however specialised;
- a professional attitude towards matters such as the design reliability and maintenance, product quality and value, marketing, safety;
- facility in oral and written communication;
- a professional approach to relationships with clients, customers and colleagues, including the supervision of staff, and the ability to work as a member of an engineering team.

IEng degree courses may include such subsidiary subjects as Business Management or Languages, always provided that mainstream engineering science and technology dominate, whether of a single or multidisciplinary nature.

ACCREDITATION PROCEDURE

The QAA system described above applies to all UK degrees, including those in engineering. Its purpose, however, is simply to ensure that the level and quality of study is broadly appropriate for a UK university degree – a *general* rather than specific assessment. In addition most professional areas, including engineering, have their own accreditation procedures, usually operated by the professional institutions. The distinction compared with the QAA is that the purpose of accreditation is to assess whether the degree is appropriately directed towards a *specific* activity such as Civil, Mechanical or Electronic Engineering.

'Accredited Courses', which are judged to meet SARTOR requirements, mean that MEng and IEng graduates automatically fulfil the academic base requirements for CEng or IEng (Figs 5 and 6). For this reason, almost all university engineering departments apply for their courses to be accredited, because without accreditation they would be greatly hampered in their efforts to attract well-qualified students.

The advantages for the students are that, besides being assured of fulfilling the requirements for registration, they are spending their time at an important point in their lives on courses and programmes which have been thoroughly vetted to high standards and therefore give the best prospect of later advancement in the profession and practice of engineering.

A university engineering department seeking accreditation of a course (Fig. 7) must submit full details to an Engineering Institution (e.g. the Institution of Civil Engineers) licensed for the purpose by the Engineering Council. The course details include objectives, curricula, facilities, resources, staffing, student assessment methods and industrial links. The application is considered by a committee which includes academics and industrialists and if there is a prima facie case for

Fig. 7. Summary of the UK accreditation system.

accreditation a visit to the university department will be organised by the Engineering Institution. The purpose of the visit is to inspect the facilities, meet students and staff and to explore any questions arising from the written submission. A decision is then taken whether to accredit the course and for how many years, with a maximum of five.

THE CONCEPT OF THE MATCHING SECTION

The increases in course length stipulated in the latest SARTOR involve for universities greater costs per student and also additional expense for engineering students themselves by way of tuition fees and living expenses. This is at a time when the UK university system generally is coming under considerable financial strain due to the greater participation rate and annual cuts per student place in government support for higher education.

In these circumstances the Engineering Council has judged it advisable to provide alternative pathways to achieve full qualification in engineering. Some students can, by preference or financial necessity, enter courses which are one year shorter but are then supplemented after graduation by a 'Matching Section'.

The Engineering Council has adopted the special term 'Matching Section' to characterise the planned and verified effort of an individual either to *complete* a qualification – or to take the larger necessary step to a *higher level* of qualification, for example from IEng to CEng – a vertical matching section.

The character of the Matching Section

The Matching Section required by three-year honours graduates (Fig. 5) to complete their educational base for Chartered Engineer must include the learning equivalent to one further academic year of study. The main aim is broadening to achieve equivalence with four-year graduates, both in foundation learning and specialist enhancement. There are a number of means by which this may be accomplished. For example:

- an Integrated Graduate Development Scheme, carried out in partnership between an employer and a university;
- accredited employer-led learning;
- an appropriate one-year Master's course;
- a one-year (or equivalent) course in a different field at advanced undergraduate level.

A similar set of requirements and pathways is being established for those who take a two-year full-time diploma course (Fig. 6). With the addition of a Matching Section they can complete the educational base for Incorporated Engineers.

Providers of the Matching Section

1. *Universities.* Universities may provide specific part-time or modular courses to bridge the gaps between three-year degree provision and their four-year programmes.
2. *Employers.* Some large employers will wish to make a major contribution to Matching Section programme design, to ensure that educational attainment developed in the workplace, or in partnership with universities, is relevant to employment needs and receives appropriate academic accreditation.
3. *Professional Engineering Institutions.* Professional institutions often endorse university and employer-provided education. In specialist areas, or when responding to the needs of individual members, they may wish to sponsor preparation for specialist qualifications relating to the particular institution.

Quality assurance of the Matching Section

As the Matching Section allows some students to gain registration having followed a shorter degree course, it is vital that the Matching Section should be academically credible. In each case its content and mode must be planned and then verified on completion and be subject to competent regulatory control. In the UK this responsibility for quality assurance falls to those engineering institutions which are licensed by the Engineering Council to undertake accreditation.

UK PARTICIPATION IN INTERNATIONAL AGREEMENTS ON MUTUAL RECOGNITION

The International Committee of the Engineering Council carries the responsibility for negotiating and operating agreements with groups of other countries on the mutual recognition of engineering qualifications. (However, in some cases individual UK professional institutions may make agreements with their equivalent body in one other country, so-called bi-lateral agreements.)

There are two group agreements in which the UK participates:

1. The 'European Engineer' (EurIng) title.
2. The 'Washington Accord'.

It happens that these exemplify two of the possible three main types of international agreements on mutual recognition of qualifications.

The EurIng title awarded by FEANI – the Federation of European National Engineering Associations – operates in 27 countries, including all those in the European Union [4]. It is awarded to those professional engineers who have fulfilled the academic requirements in their own country, plus several years' validated training and experience. Each candidate is vetted by the local National Monitoring Committee (NMC) and

then by the European Monitoring Committee (EMC). There are currently some 22,000 EurIngs. This coupling of education, training and experience necessary to attain the qualification is much in the UK tradition, so its operation presents little difficulty, because practically all Chartered Engineers will automatically fulfil the requirement.

The second international agreement, the 'Washington Accord' does not go as far as the EurIng formula. The eight participating countries (Australia, Canada, Hong Kong, Ireland, New Zealand, South Africa, USA and UK) agree to recognise each other's accredited degrees. However, candidates for a national title still have to fulfil all the other local requirements. In negotiating both agreements, it has to be said that the UK found itself in some difficulty because of the relatively short three-year duration of most of its accredited degrees. Other Washington Accord countries generally have four-year degree courses, while those in Continental Europe are often five, six or even seven years long – though such longer courses would often include some training.

It is a tribute to the flexibility exhibited by our colleagues in other countries of FEANI and the Washington Accord that the UK three-year degree has been accepted as satisfying the academic standards. Fortunately, the problem will diminish when the new SARTOR requirement comes on stream for Chartered Engineers to have a four-year educational base.

It was mentioned above that EurIng and the Washington Accord represent two of the possible three types of international mutual recognition agreement. In fact, they both fall short of the third type, which would be a comprehensive agreement allowing engineers attaining the professional title in their own country to move to another participating country and use the professional title of the host country without further examination.

It is believed that no such examples exist and it is not clear that such agreements are feasible or even desirable. Aside from political barriers, there is the real problem of different education, training and qualification systems. For example, from the UK point of view it would be extremely difficult to admit to the CEng title anyone who had not taken a Professional Review including an interview.

The EurIng system neatly avoids the problem of such international differences by the award of a new common title. Even a EurIng holder, wishing to use the designatory letter of any country other than their own, still has to complete the requirements of that country.

The Engineering Council and the UK Professional Engineering Institutions as a whole are firmly committed to operating the EurIng title and the Washington Accord, and to continue negotiations on further mutual recognition developments. The aim is to assist individual engineers in their mobility and assist their employers in the appreciation of qualifications gained in different countries across the world.

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J. C. (Jack) Levy, OBE, FREng, was educated at the University of London and the University of Illinois. He became Head of Department of Mechanical Engineering at the City University, London and was Pro Vice-Chancellor of the University. Later, at the Engineering Council in London as Director, Engineering Profession he carried responsibility for defining national standards of engineering education and training. He was also responsible for international contacts and was one of the originators of the Washington Accord on mutual recognition of accredited degree courses. Recently he returned temporarily to the Engineering Council to supervise the preparation of the latest upgraded edition of SARTOR (Standards and Routes to Registration), the subject of the present paper. He has received honorary doctorates from four universities and was elected in 1988 to the Royal Academy of Engineering (the UK National Academy).

'Since this paper was written, a modified system of Quality Assessment at subject level has been announced in the UK. Judgement will be made on three aspects of provision:

- Teaching and Learning
- Student Progression
- Learning Resources

Each of these will be placed in one of three categories – Failing, Approved or Commendable. These will eventually replace the 1–4 numerical assessments. A single overall judgement will be made on whether the provision is 'Failing' or 'Adequate' for the whole subject area'.

APPENDIX 1

Quality Assurance Agency – Assessment Framework

1.	Curriculum: design, content, organisation	1.	Level (diploma, under-graduate, taught post-graduate)	Is there evidence that curricula have been designed specifically in order to achieve the stated aims and objectives?
		2.	Intended outcomes of teaching and learning	
		3.	Content and structure	Are students fully aware of the curricula contents? Do curricula equip students with an appropriate range of specific and transfer-able skills?
		4.	Modes of study	
		5.	Opportunity for: • Progression to post-grad studies • Continued personal development • Developing subject-specific generic/ transferable skills	
2.	Teaching, Learning and Assessment	1.	Strategy/methods for teaching, learning and assessment	Are the teaching methods described?
		2.	Structure and range of the programme of teaching and learning activities	Is there a clear indication of the range of opportunities for student learning (including independent learning?)
		3.	Opportunity for and assessment of: • Development of knowledge studies • Development of understanding and other intellectual abilities • Development of subject • Specific skills development • Development of generic/transferable skills • Development of independent learning abilities • Development of values, motivation, or attitudes to learning	Is there evidence that assessment is used to promote learning as well as a means of judging individual performance? Are the assessment methods appropriate
3.	Student Progression and Achievement	1.	Measures of annual progression/completion of a year 'in good standing' and	Is there evidence related to student progression
		2.	completion/non-completion of programme. Qualifications awarded.	and achievement? Is non-completion explained? Do graduates and diplomates obtain relevant employment or go on to further study?
4.	Student support and guidance.	1.	Overall strategy for support and guidance.	Are there effective mechanisms for academic
		2.	Admission and induction arrangements.	and pastoral support of students?
		3.	Academic tutorial support.	
		4.	Remedial support.	
		5.	Pastoral and welfare support.	
		6.	Career information and guidance.	
5.	Learning Resources	1.	Overall strategies for learning resources.	Are the human and physical resources matched to the achievements of the aims and objectives?
		2.	Library.	
		3.	Equipment.	What is the impact of staff research and scholarship on the delivery of curricula?
		4.	Information technology.	
		5.	Teaching and social accommodation.	Do staff avail themselves of the opportunities for professional development?
		6.	Technical/support staff.	
6.	Quality Assurance and Enhancement	1.	Internal** quality assurance and linkage with the institution-wide quality assurance.	Is there evidence related to student progression and achievement? Is non-completion explained? Do graduates and diplomates obtain relevant employment or go on to further study?
		2.	Staff development related to teaching and learning.	
		3.	Appraisal of teaching skills.	
		4.	Comparability of qualifications.	
		5.	Impact on student experience.	

Notes

A. The core set of aspects of higher education provision provides a common structure for self-assessment, assessment visits, judgements and reports.

B. Mere assertions as to the quality of provisions are not enough. Must be supported by evidence.

C. Major sources of evidence are: present and past students, staff, external examiners and moderators, subject peers, external advisers, validating and accrediting bodies, professional bodies and employers.

D. Assessors will use an assessment scale to assign grades to the individual 'aspects of provision' and will derive an overall judgement from the grades.

E. Grades are:

1. Unsatisfactory: the aims and objectives are not met; there are major shortcomings that must be rectified.
2. Just acceptable: the aims and objectives are broadly met, but significant improvements could be made.
3. The aims and objects are met; however, there is scope for improvement.
4. The aims and objectives are fully met.

(**) Subject-provider level: for example, curriculum or course review, feedback mechanisms.

APPENDIX 2

UK engineering qualifications

Chartered Engineer (CEng). Chartered Engineers are concerned primarily with the progress of technology through innovation, creativity and change. They develop and apply new technologies, promote advanced designs and design methods, introduce new and more efficient production techniques and marketing and construction concepts, and pioneer new engineering services and management methods.

Incorporated Engineer (IEng). Incorporated Engineers act as exponents of today's technology and, to this end, they maintain and manage applications of current and developing technology at the highest efficiency. Incorporated Engineers require a detailed understanding of a recognised field of technology, so they can exercise independent technical judgement and management in that field.

Engineering Technician (EngTech). The roles of Engineering Technicians involve them in the application of proven techniques and procedures to the solution of practical problems. They carry a measure of supervisory and technical responsibility and are competent to exercise creative aptitudes and skills within defined fields of technology, often under the guidance of Incorporated Engineers. They apply safe systems of work.