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Engineering Formation in the UK

V. D. VANDELINDE
University of Bath, Claverton Down, Bath BA2 7AY, UK

This paper looks at the process of 'formation' of engineers in the UK. The term derives from the Report of the Finniston Inquiry into the Engineering Profession Engineering our Future *[1] published in 1980 which has had a profound influence on engineering education in the UK, especially relating to initial formation. I shall look at its key proposals relating to 'formation' before comparing a number of aspects of current practice in the UK and the US. I shall conclude by considering some issues currently preoccupying the UK engineering educators, and the profession more generally. My observations are based on some six weeks residence in the UK as Vice-Chancellor of the University of Bath and on the points of comparison with the US system that have struck me during this time.*

THE FINNISTON INQUIRY AND REPORT

THE FINNISTON INQUIRY was set up by the Secretary of State for Industry in the late 1970s with a very wide brief which might be summarised as 'finding a cure for the ills and decline of UK manufacturing'.

Formation

Many of the proposals in the Finniston Report were based on the belief that appropriate education, better integration of engineering with other industrial disciplines and due recognition of the professional status of the engineer would enable UK industry to compete far better especially against the key rival at that time, West Germany. Central to Finniston was the belief that engineers should receive a full and balanced 'formation', a term selected '. . . to convey the progressive process through which a young engineer develops his or her technical or personal capabilities. This process . . . can only be properly brought to fruition in the working environment in which he or she will practice as an engineer. . . . The formation process thereafter is one which will continue throughout each engineer's working life . . .' [1, IV.a.4.1]

Training routes

Finniston set out proposed training routes for three groups:

- the main body who would take degree level qualifications;
- high fliers;
- technicians.

Details of Finniston's proposed streams of formation are shown in Table 1.

The main body. The main cohort would receive an educational package made up of the three-year Bachelor of Engineering degree (B.Eng.) plus structured postgraduate training and experience. The primary emphasis was to be on the synthesis of basic subjects and development of students' design and problem-solving capabilities through progressive project work and design practice.

High fliers. These students were to be selected after a common first year of the B.Eng. and would be given a package made up of the Master of Engineering (M.Eng.) lasting four years in total, and oriented towards design, synthesis and engineering applications together with structured postgraduate training and experience. Students would be selected for this route by assessment of both academic attainment and personal aptitudes.

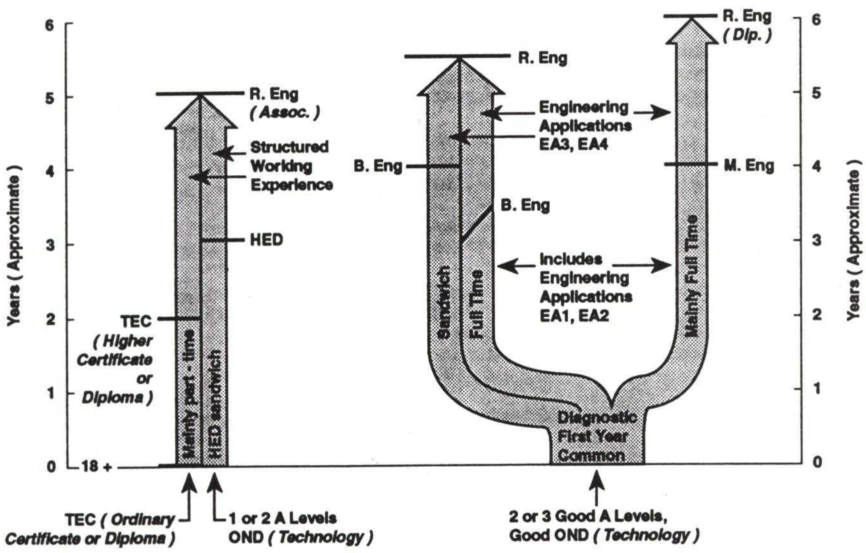
Technicians. This group of students would gain a pre-degree level qualification and similar combination of theory, application, and experience.

Each strand of the initial formation was to comprise an integration of theory, application and experience throughout. To reflect this inclusion of learning through experience, the degrees were to be differently named, the Bachelor of Engineering B.Eng. rather than B.Sc. or B.Sc.(Eng.), indicating that they are quite distinct from applied or pure science courses. To ensure that engineering applications were taken seriously, compulsory modules were specified, known as Engineering Applications (EA) with EA1 and EA2 being built into the degree stage and EA3 and EA4 into the postgraduate experience.

Postgraduate industrial formation

'We believe intending engineers must complete their initial formation in the working environment.' [1, 4.63] 'The provision of postgraduate training along the lines of EA3 and EA4 is essential for the success of the formation packages. We place responsibility for this squarely upon employers. The industrial phase will be vital.' [1, 4.68].

Table 1. Main streams of formation for engineers in the Finneston Report



Accreditation and registration

Finniston recommended that the B.Eng. and M.Eng. degree courses were to be externally accredited and that a statutory National Engineering Authority should be set up, with individuals satisfying this authority that they met the full formation requirements before applying for compulsory registration. Compulsory registration was intended significantly to upgrade the status of the engineering profession.

CURRENT PRACTICE IN UK ENGINEERING FORMATION

Having set the background of Finniston, I now move to examine current practice by looking at a number of points of comparison including:

- pre-university qualifications and admissions policies;
- range of engineering degrees;
- course structures including practical element;
- modular degrees and credit transfer;
- specialist subject teaching;
- teaching methods;
- examinations and assessment;
- postgraduate industrial training;
- accreditation and registration;
- continuing professional development.

I shall draw on what I perceive to be happening at Bath as a case study.

Pre-university qualifications and admissions policies

Traditionally, university applicants in England and Wales (not including the former polytechnics who gained university status last year) will have been streamed from age 16, if not earlier, towards the three or more rarely four A level (Advanced) subjects that they will take at 18. Their choice of A level subjects either influences or is related to their likely choice of subject at university. There are other entry routes and much debate about 'access' i.e. entry for students without the traditional A level qualifications. (Here it should be noted that the educational system that covers England and Wales differs in a number of aspects from the systems in Scotland and Northern Ireland, particularly in pre-university education.) This pattern also requires an obvious early commitment to science or engineering as compared to the US. American students can and do make early choices that exclude careers in science or engineering, but they may also hold their options open much later in their education.

A major difference between the UK and the US is the low percentage of pupils in the former, who stay in school after age 16. Taking 1987 figures, participation in full-time education for 16 year olds in the UK (not just England and Wales) was 50% compared with 95% in the US, while for 16–18 year olds it was 35% and 80% respectively. The British Government aims to increase participation, and the figure for 16 year olds for 1991 just published shows a rise to 67% [2]. The explicit aim is for 1 in 3 of the 18 year olds to go on to higher education by the year 2000, a doubling of numbers in a period of about 12 years, although without commensurate increases in funding.

The total entrants to UK universities for Engineering and Technology in 1991 [3] was

men	9 288
women	1 595
total	10 883

The polytechnics accounted for another 5000, approximately. A breakdown of the 1991 entry appears in Table 2.

Bath has high admissions standards with its

Table 2. Home applicants (i.e. UK–EC) applicants accepted for university entrance in engineering and technology 1991

	Men	Women	Total
General engineering	826	162	988
Civil engineering	1590	307	1897
Mechanical engineering	1631	187	1818
Aeronautical engineering	525	41	566
Electrical engineering	173	24	197
Electronic engineering	1495	130	1625
Production engineering	310	96	406
Chemical engineering	774	224	998
Minerals technology	71	11	82
Other engineering	87	11	98
Other single subjects	399	240	639
Combination subjects	1407	162	1569
Total	9288	1595	10 883

entering students rated the fifth best among university entrants, based on examination scores. Engineering admissions policies tend to specify two required or core subjects and a total minimum grades score, e.g. Mathematics, B grade, and Chemistry, C grade, with a third unspecified A level, all three to add up to a certain minimum score.

This starting point is quite different from the US, in that while standardised tests and high school grades form much of the admission criteria, many universities also consider other broad personal factors in making their admission decisions.

Range of engineering degrees

Most of the Finniston proposals for the initial formation have been implemented. The B.Eng., a three-year honours degree, is well established and is perceived as a different and distinctive type of degree, while the M.Eng. is, perhaps, less well established. Bath's engineering departments all offer B.Eng. degrees which are accredited by the appropriate institution, IMechE, IChemE, IEE, etc., as providing the approved academic training required for professional membership and registered Chartered Engineer status. The institutions accredit universities in the UK and, in some cases, overseas.

The M.Eng. includes areas of Chemical Engineering, Electronic and Electrical Engineering, and Materials Science, and will include Mechanical Engineering. These are 'enhanced' undergraduate degrees, selected from the main B.Eng. subject range and are not postgraduate degrees.

Unusually, compared to other universities, Bath runs sandwich degrees. Students take periods of supervised industrial experience and training which contribute towards their degree, very much in the philosophy of Finniston as they integrate theory and application. The sandwich comes either as:

- thin sandwich, having two periods of 6 months industrial training in a four-year degree;
- thick sandwich (more common) with 12 months industrial placement between second and final year.

Sponsored students who are partially supported by companies that will require their employment for a specified period after graduation, often follow a 1:3:1 pattern of a year industrial training before and after a three-year degree. This is not considered a sandwich degree.

This 'real work' experience makes graduates from these programmes highly employable, and tends to encourage them to stay in their subject area at least initially. Although different in detail, these sandwich courses are very much like typical US co-operative education schemes. The goals are identical and the overall fraction of the educational experience spent in industrial training is similar.

The UK norm is for engineering degrees to be geared to a particular branch of engineering; thus applicants at age 17 mainly choose not merely engineering, but also the branch, e.g. Mechanical Engineering or Chemical Engineering. Bath's degrees follow that pattern, and not the Engineering Science model. Within the branches, the variation offered to students is considerable though more detailed choices are made once the degree is under way. At Bath, within the three largest engineering departments, students have an extensive choice [5].

Mechanical Engineering degrees

The department offers: B.Eng. in Aeronautical Engineering, B.Eng. in Mechanical Engineering, B.Eng. in Manufacturing Systems-Engineering and Management and B.Eng. Engineering and Languages, in three-year full-time or four-year sandwich programs. An M.Eng. is being drawn up.

Two degrees deserve special mention. Manufacturing Systems-Engineering and Management is a combined engineering with management degree, which aims to teach the disciplines required to develop a design through to a saleable commodity. After a first year common with other Mechanical Engineers, second year students take specialised engineering and management courses, taught by staff from the School of Management, in accounting, industrial relations, marketing and business systems. Final year students select engineering and management options as well as taking core courses (design and experimental projects, CIM systems and OR techniques).

Well established, though now much more fashionable, is the B.Eng. in Engineering with either French or German as combined Honours. The students follow a specifically designed language course taught by the Modern Languages Faculty which also provides an education in current social, political and cultural aspects of the country. French and German engineers are on the staff to ensure that the students acquire a suitably technical understanding and that this integrates with their engineering studies. The students spend three months on placement abroad, and produce a report as part of their degree in the foreign language. In addition, the design project is often sponsored by French or German firms.

Electronic and Electrical Engineering degrees

These degrees offer a similarly extensive list of variations including B.Eng. in Electronic and Communication Engineering, B.Eng. in Electronics and Applied Engineering, and a broader based B.Eng. in Electrical and Electronic Engineering which includes a major project management dimension in three or four-year sandwich mode.

The recently redesigned M.Eng. is offered as an enhancement of each of the three streams, to provide flexibility to the student and to the Department. This is important since the attractiveness of the M.Eng., which requires an additional year of study, is uncertain in a time of recession.

A popular choice with applicants is the Single Market dimension which has been built into the three streams as an M.Eng. for students who already have foreign language skills from the GCSE national exam, taken at age 16. They can develop their linguistic skills, take a vacation work placement in the overseas country, and then spend about five months of their final year at a European university (at the Institut National Polytechnique du Grenoble, Institut National Polytechnique de Lorraine, Braunshweig Technical University or the University of Genova, amongst others). This time is spent studying alongside final year European students before returning to complete their design project and dissertation. Contrary to some expectations, the students who have completed this M.Eng. fit in well technically and linguistically abroad, suggesting that the technical gap is not as wide between the European and the UK engineering formation models as was feared or expected.

Chemical Engineering degrees

Chemical Engineering, with an intake much smaller than Mechanical Engineering, or Electrical and Electronic Engineering, offers two main degrees, Chemical and Bio-Process Engineering with a similar range of variations in three and four-year sandwich mode. A new four-year M.Eng. in Chemical Engineering and Environmental Management is just starting with some final year courses that will be taught by subject specialists outside the Department, in Economics and Management for example.

I am not including engineering degrees offered within the Schools of Architecture and Building Engineering, and Materials Science which raise other issues.

Course structure including practical element

As many of the UK degrees aim to produce initially trained specialist engineers, the degrees are tightly structured in comparison with the US, and students would not normally take courses outside the requirements of the degree, such as humanities or social sciences. Within the degrees, as indicated, there are language options, and management or social science courses, but these are part of the degree structure. Increasingly, language options are being offered as extras.

Remembering the Finniston concern with Engineering Applications, much of the ground of EA1 and EA2 is covered by sandwich training or is built into the degree either through practical and design work or in separate add-ons. Mechanical Engineering organises courses which are taught by external staff covering manufacturing processes and engineering materials in the hands-on way intended by Finniston.

Modular courses and credit transfer

There is almost no common teaching between the Engineering Departments at Bath, a historical feature arising from the size and professional identity of the different departments. There is common teaching within the department for their first year and part of the second year, before the students diversify, and growing pressures on resources will probably stimulate more common teaching across the subjects.

There are moves towards modularisation as a course structure which is now gaining ground in the UK. However, at present it would be exceptional for a student to change universities during their course in the UK or even to take a break from university, other than for academic reasons, placement or exchange. Most students in the UK are supported by a grant and loan for their maintenance and have their tuition fees paid by their Local Education Authority and would go straight through their three, four, or five-year degree programme. The notion of credits, acquisition, and transfer is currently unfamiliar in the UK as is, to a very great degree, the idea of changing major subject, even at the same university.

Teaching specialist subjects

The accrediting bodies in the UK appear not to stipulate that specialist subjects are taught by a subject specialist. The Bath Senate (academic body) does hold this as a general principle though this has become distorted by an academic issue and a resource issue: how far should the subject teacher be, not merely research active, but also a research collaborator with that department? How are the finances transferred? It is easier to handle when there is a two-way trade. This becomes more complex in the UK context because of the cascade effect, which is the view that university teachers should be research active in the subject they teach. Linked to this, especially an issue in engineering education, are the questions about the depth of knowledge required in a specialist subject with mathematics not surprisingly being the most debated.

Teaching methods including design

In the UK, contact time can vary for engineering students from between 20 and 25 hours per week. This time is made up of large group lectures (12–14 hours) smaller groups in tutorials, seminars and problem classes (3–5 hours), and laboratory classes (5–7 hours). Overall this is similar, albeit organised differently, to contact time in the US. There are moves to reduce the contact time for pedagogical reasons as much as for resource reasons.

A feature of UK engineering education is the equipment-based laboratory sessions, 5–7 hours per week. Tutorials or seminars are run for varying sized groups. A key part of the staff/student contact is via laboratory classes when students are working on projects with a number of staff present. Because of insurance and safety factors, these are always supervised by staff at Bath even if post-graduate students are present as demonstrators. Most laboratory reports are also marked by staff, which is a more debated use of academic staff time. Computer simulations are used far less than in the US and there is more attention to practical applications.

While all UK engineering degrees include a design element as Finniston recommended, the Bath degrees give special attention to design. In Mechanical Engineering, students take design courses in their first and second years; additionally, all final year students work through a two person experimental project and a group (3 or 6 person) design project. This project runs throughout the year, and concludes with a public lecture and design exhibition including actual demonstrations. In the new E and EE degrees, all students will now take a design project in their final year. These are broader based than those of Mechanical Engineering, as the students form a small 'company' to develop a business plan and marketing strategy in addition to product design.

Chemical Engineering runs design projects in each year. The first year projects are developed from operational problems at National Starch Co. The students work in groups of 4–5 to produce a target quantity of products. Two plant managers come down to assess the projects and to discuss the students' work and the winning team win a prize as well as good marks.

These design experiences are similar to the best notion of the capstone design requirements recently introduced in the US by the Accrediting Board for Engineering and Technology (ABET).

Examination and assessment

Although individual components may be shorter, the syllabuses are usually organised on an academic year basis (9 months). First year grades are generally used to assess progress and allow entry to the second year, and do not count towards the final result. Second and final year grades count towards the final degree result classification and are usually a combination of assessed course work and examination. Built into each year is a revision period seen as important in enabling the student to integrate the different strands of the year's work. Project work is assessed differently, on design drawings, reports, models and oral presentations. For all examinations or assessment leading to degree results, there are external examiners, academics from elsewhere, and industrialists, involved in drawing up and marking question papers to ensure objectivity and standards.

Thus, an Honours degree from one UK university is more standardized in its meaning than a degree at a given grade point in the US.

Postgraduate industrial training

The Finniston proposals for initial industrial training specifies two accredited blocs, EA3, an introduction to industry, and EA4, specific training for first responsible position. These proposals have been at least partially adopted, though a major problem is that engineering companies, crucial at the post-degree training stage, have had to slim down with some consequent reductions in training.

In practice there is variation between the institutions, though all require supervised work experience. The IMechE supervises much industrial training through the Monitored Professional Development Scheme (MPDS). This program involves two years of training followed by two years of planned development. The planned development phase is worked out in agreement with the trainee, the employer, the IMechE and the Principal Industrial Mentor, who is a C.Eng. responsible for supervising the scheme. A feature is the outline training plan required from the sponsoring organisation.

The IEE UK accredits training schemes, usually those of the larger rather than the smaller recruiters. In comparison the IChemE has a less formal structure, but requires coverage of specific categories of experience prior to application for membership.

Accreditation and registration

Degree accreditation has a dual purpose: the institutions accredit degrees in relation to their own membership, and 15 institutions are authorised to accredit degrees on behalf of the Engineering Council. Graduation from these degrees is recognised towards Chartered status. Such graduates would be eligible, after completing their industrial training, to apply for full membership of their own professional institution. This membership precedes the application to the Engineering Council for Chartered Engineer status, which is voluntary. The C.Eng. is recognised by the European Federation of National Engineering Associations (FEANI). (The Engineering Council has not emerged with the role desired by Finniston, but has a co-ordinating role overarching the individual institutions.) Insurance requirements as well as the Single Market are now stimulating more engineers to seek C.Eng. registration. Table 3 shows the

Table 3. Institute registration records, 8 May 1992

Institution	Stage 3 C.Eng.	Total†
ICE	46 426	49 782
IMechE	45 490	55 395
RINA	2780	3035
IGasE	2987	3852
RAeS	5484	8882
IEE	51 075	60 532
IMinE	1752	2093
IMarE	7420	10 984
IMM	2674	2705
IStructE	7213	8262
InstP	150	150
IChemE	8120	8214
IBF	123	439
InstE	2149	2395
IMet	5490	6939
NECIES	4	43
ICeram	12	15
IWEM	107	829
IMEMME	28	1493
Weldl	105	574
ILE	20	430
IHT*	1	1
IAgrE	113	847
IHospE	36	934
IPlantE	49	3854
BCS	4610	4634
BInstNDT	41	838
INucE	126	289
BioES	23	24
IESS*	0	22
IMechIE	0	6275
CIBSE	2861	5160
I Plumb	0	1670
IQA	0	1194
IAEA*	0	137
IWHM	0	1338
IRTE	0	3404
InstMC	687	1946
PRI	109	133
IWO	0	658
IED	45	2969
HKIE	44	272
ISME*	0	108
IOA	16	17
IET	0	2273
MES	11	153
IEEIE	0	22 037
IIExE	0	1204
IHIE	0	1528
Direct	0	460
Total	198 381	291 422
Female Registrants	1590	2781
Female (%)	0.80	0.95

* Non-nominated bodies.
* Total made up of EEng, IEng and EngTech.

numbers of registered engineers by institution and by gender at 8 May 1992.

Continuing professional development

Engineering-driven continuing professional develoment (CPD) is far less developed in the UK than it is in many other professions and certainly in comparison with the US. UK colleagues suggest that this reflects the different levels of the first degrees and consequent different perceived needs for the M.Sc. Able UK engineers are encouraged to stay for the M.Eng. which takes an extra year.

A great deal of post-experience training takes place but this tends to be company specific. There are preliminary proposals for an agreed number of annual CPD updating days for Chartered Engineers, and this may well be part of new formation proposals.

Bath makes some CPD provision. Mechanical Engineering is involved in the Integrated Graduate Development Scheme with a consortium of local companies and colleges who provide modules leading to an M.Sc. Also a modular specialised M.Sc. degree in Fluid Power attracts students worldwide. There are also company specific courses. E and EE is developing rather differently, possibly as befits this branch of engineering. The new degree programs have a reduced content and presuppose postgraduate updating. Additionally the Department is developing its own distance learning M.Sc. to fill this need.

LOOMING ISSUES

In my final section I shall touch on:

- the radical changes going on in UK higher education which necessarily impinge on engineering formation;
- the changing pattern of pre-university education;
- the attraction of engineering as a career and demand for engineering degrees;
- the debate about engineering degrees;
- the Single Market;
- continuing professional development.

Changes in higher education

UK higher education (HE) is going through a period of profound change. This directly affects engineering education, which is preparing for the more specific changes expected to arise out of a fundamental review of engineering formation being instigated by Sir John Fairclough, Chairman of the Engineering Council.

It is too early to assess the implications of bringing together the universities and former polytechnics for policy and funding purposes, the end of the binary divide. However, I have been struck by a sense at Bath that teaching quality (by which I mean individual student attention, which has been high and a source of pride) will deteriorate until new teaching methods giving some form of individual attention are devised and instituted. Funding initiatives are encouraging computer-aided learning to, for instance, teach mathematics to engineers, though such initiatives are presently delayed by pressures to improve research performance (at least measured by deliverables). Changes in the way universities receive their funding and the tighter link of research funding to research output is prompting closer examination of use of staff time, with potential reduction in staff/student contact.

As an aside, tighter government expenditure on HE is affecting UK students who, until recently, received maintenance grants with no payback required. Now they receive a partial grant and loan and much reduced state benefits, at a time of recession.

Pre-university education

There have been radical changes in pre-university education, primarily affecting England and Wales, through the introduction of the National Curriculum. Changed teaching methods in schools have broadened mathematics, and especially science teaching at the expense of depth. Although these students will not enter HE until 1996, the universities are already having to find ways to bridge an emerging gap in the entrants' knowledge and the level expected by universities. This is particularly a problem in mathematics, chemistry and physics. A clear benefit should be that all pupils will have studied technology—one of the core subjects. A new post-16 qualification is being introduced alongside the traditional A levels by the National Council for Vocational Qualifications which is led by employment-skills and from which at Level III or IV, students could apply to HE, with a quite different background from their A-level contemporary.

The attraction of engineering

The demand for engineering programs from students in the UK continues to decline. It is not clear whether this decline relates to the perceived unattractiveness of the degree content or the subsequent career, or to pre-entry qualifications and preferences. Numbers of applications, especially from high calibre students have been falling at a time of increasing demand for engineers, from 13% of all applications in 1985 down to 8.8% in 1990 for university admission (excluding the former polytechnics) [6]. Revision of degrees is also prompted by criticisms about excessive course content and the debate of 'teaching knowledge versus the ability to learn'. Bath's revised E and EE degree portfolio has certainly taken account of this by building in more thinking rather than knowledge absorption time. Such an approach presupposes more CPD.

There is a continuing debate about the desirable number of engineering graduates and the degree to which existing graduates are optimally used.

How long should engineering degrees take?

There are contradictory tensions from Government for 2 year degrees (abbreviated or compressed) at the very time that the Engineering profession itself is trying to move from three to four-year degrees and to upgrade qualifications to be perceived as comparable with those of other EC countries. (The EC Directive 89/48/EEC gives the right for suitably qualified professionals from member states to have their qualifications recognised by other national professional bodies; the UK engineering community is fully aware of the longer education time of European, especially German, engineers, together with their lack of practical experience.) Some UK universities have moved to a four-year full time pattern as standard for their engineering degrees though this requires government agreement for the funding. However, Sir John Fairclough, Chairman of the Engineering Council, has suggested a 2 + 2 model with the first two-year course common for both incorporated (i.e. technician grade) and chartered engineers. This is at a very preliminary stage of discussion but would bring a number of changes in its train if introduced.

The pattern proposed would be:

Stage 1 Basic two years, followed by streaming;
Stage 2 Education and training jointly provided by HE and industry;
Stage 3 Experience provided by industry.

The Single Market

I have already referred to some of the implications for engineering formation of the UK being a part of the Single Market and I shall not say more here, other than to stress the importance of the Single Market as a driver for change.

CONCLUSION

It is not appropriate for this paper to conclude in any formal way—I have been in the UK for too short a time to do more than think about some of the impressions that I have gained, and some of the issues that are uppermost in the minds of my engineering colleagues. Many of these issues are open-ended at present anyway. There are real challenges facing the UK engineering educators and I do not underestimate them.

Acknowledgements—I am grateful to Professor Keith Foster, Director—Engineering Profession, Engineering Council, for access to some of his unpublished papers.

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V. David VandeLinde, an electrical engineer, received his first, masters and doctoral degrees from Carnegie-Mellon University, USA. He was appointed a member of the Faculty of The Johns Hopkins University in 1967, becoming a full professor in 1977. He was appointed Dean of the Whiting School of Engineering in April 1978, assuming leadership as part of the school's re-establishment as a separate entity within the university. Professor VandeLinde was appointed Vice-Chancellor of the University of Bath, UK in August 1992.