The Irish Journal of Education 1981 xv 1 pp 62 83

SCIENTIFIC EDUCATION IN ENGLAND AND GERMANY IN THE SECOND HALF OF THE NINETEENTH CENTURY

G W Roderick*
Sheffield University
and
M D Stephens
Nottingham University

This paper begins by examining the growth and development of scientific and technological studies in English civic universities in the first half of the nineteenth century the factors which hindered such growth the rate of production of graduates and the opportunities available to them It goes on to contrast scientific education in England and Germany The origins and development of the German universities and technical high schools particularly in the context of chemical and engineering education are examined

Prior to the nineteenth century the English universities had fulfilled a variety of needs, as well as catering for the needs of the church, politics, and the traditional professions of law and medicine they also appealed to the gentry as a means of social advancement The early pioneers of the Industrial Revolution, on the other hand, were not university men and owed little directly to the ancient universities of Oxford and Cambridge which had neglected the sciences It was in the Dissenting Academies and the provincial societies that science had found a natural home in the eighteenth century, the disinterest of the universities was to continue well into the nineteenth century, the two London colleges, University College and King's College, doing little to change this in their early days It was not until the formation of the Royal College of Chemistry and of the Royal School of Mines in the early 1850s that institutions of learning having some bearing on industrial needs were created in England

The older universities were antagonistic to vocational training Their thinking, expressed most cogently by John Henry Newman, John Stuart Mill, and Mark Pattison, was dominated by the ideal of a liberal education, the basis of which was the study of classics and mathematics This was

* Requests for off prints should be sent to Gordon Roderick, Division of Continuing Education, University of Sheffield, 156 Broomspring Lane, Sheffield, S10 2FE

considered to be an education fitted for a gentleman who might follow it with further study to enter politics, the Church, law, or medicine. Most students, however, entered university only to be educated in the right and proper manner as befitted a gentleman. John Stuart Mill, in his inaugural address as Rector of St Andrews University, claimed that universities were not the place for professional education, the purpose of university education rather being to inculcate a courteous and noble bearing in the conduct of life and to produce capable, cultivated human beings. Newman, like Mill, opposed professional studies and wrote of university education in terms of the acquisition of delicate taste and of the cultivation of the mind. From around mid century onwards, this view was increasingly opposed by a vociferous band of protagonists, whose leading exponent was Thomas Henry Huxley, who asserted that science had as much value as had classics and mathematics as an intellectual discipline and that university education should include professional and vocational studies. Although the view of this 'scientific lobby' gradually prevailed, there is little doubt that adherence to liberal traditions was a stumbling block to the acceptance of science and even more to the acceptance of technological studies.

The acceptance of science was considerably hastened by increasing concern engendered by the threat of foreign competition, in particular the growing commercial power of Germany. During the third quarter of the century, British industry began to be overtaken by American and German industry in several major fields. In the early part of the century, the German school system had been reorganized, science being given an important part in the curriculum. The ensuing demand in the universities for science teachers together with the needs of a rapidly growing industry were met by the addition of philosophical faculties which were to produce the cadres of new scientists. Additionally, from 1820 onwards, there was a parallel growth of technical high schools – in essence technological universities. It was natural, therefore, for many English observers to view with alarm the growing menace of German education, technology, and industry.

In England, the entrepreneur was blamed for his lack of scientific knowledge and for a negligent attitude to science education. The deficiency in graduate scientists, engineers, and managers was overcome for a time by attracting German and Swiss trained personnel but it could not be disguised that an industrial economy was growing rapidly without a corresponding increase in the university population to produce scientists and engineers needed by more scientifically based industries. It was thus the underlying fear of German competition and the relative retardation of our industrial production vis a vis our competitors which led to a change in attitude to science education and professional studies and provided the momentum for the creation of new universities

The purpose of the first part of this paper is to examine the develop ment of scientific and technological studies in the English civic universities and the problem of the production of trained scientific manpower, a problem that the creation of the civic universities was intended to solve A civic university may be defined as one which has its origins in community initiatives and which was dependent for financial support on local business men and industrialists Manchester gave the lead with the creation of Owens College in 1851 In the decade 1871-1881, six new colleges were founded the Armstrong College of Physical Science Newcastle (1871), the Yorkshire College of Science Leeds (1874), Firth College Sheffield (1874), the Mason College of Science Birmingham (1880), University College Nottingham (1881), and the University College Liverpool (1881) It is clear from the titles given to three of the colleges that the fostering of scientific studies was their principal aim, in order to attain university status, arts faculties had to be grafted on to the original science colleges

In the face of financial difficulties, an imperfect system of endowments, inadequate scholarships and research fellowships, and the poor quality of student entrants, the task of the new colleges was not an easy one That they ultimately succeeded after a prolonged gestation period is evidenced by the number of students who graduated in science and technology during the period 1870 to 1910 (10,910 in science and 3,420 in technology) But merely to record the number of graduates in this way does not give a true picture of the number of students who received some degree of training, for a number of reasons, degree successes formed only the tip of the iceberg

SCIENTIFIC EDUCATION IN ENGLAND

The civic universities

Although great advances were made in the adoption of a wide variety of technological studies at university level as a result of the initiatives taken by the civic universities, the credit for pioneering the physical sciences and engineering in England belongs to University College London (1826), King's College London (1828), and Owens College Manchester (1851) University College London achieved the distinction of being the first to appoint a professor of civil engineering when in 1840 it created a chair in this subject (3) In 1847, a second chair – mechanical engineering – was added A chair in chemistry was established when the college was founded and a second one – in practical chemistry – was created in 1844 An unusual move was the founding in 1878 of a chair of chemical technology The governors of King's College were also determined to make engineering a distinctive feature of the teaching of their college and Departments of Manufacturing Art and Machinery and of Land Surveying and Levelling were set up, these were changed in 1866 to Departments of Mechanical Engineering and Civil Engineering respectively The college was a pioneer in other directions, too, for it instituted the first university chair of metallurgy in 1879 and the first chair of electrical engineering in 1890 The most significant contribution of Owens College lay in the field of chemical studies, under Sir Henry Roscoe a reputable school of chemical research was established Roscoe was instrumental in attracting Carl Schörlemmer, a German trained PhD, to the college as a lecturer in organic chemistry In 1874 Schörlemmer was appointed Professor of Organic Chemistry This was the first chair of organic chemistry at an English university and the lateness of the appointment is indicative of the neglect of organic chemistry in the universities, a neglect which is difficult to explain

Turning to the newer civic colleges, one feature is found to be common to all of them, namely the slow rate of growth of the numbers successfully completing degree courses In addition to degree programmes, colleges had also established a variety of courses which met local needs and which did not require such prolonged periods of residence as did the degree courses

Common features were found in the studies offered by the colleges, but a greater variability is also apparent than was the case with German universities and technical high schools The reason for this is simple Owing little to the intervention of central government, the civic colleges were essentially local creations and responded to the industrial needs of their local communities Thus coal-mining was emphasized at Newcastle, Sheffield, and Nottingham, metallurgy at Birmingham and Sheffield, and dyeing and textiles at Leeds Another feature of the colleges was the way in which they readily adopted non degree work One and two year courses leading to the award of certificates, certificates of proficiency, diplomas, or associateships of a college were found in mining, metallurgy, brewing, various branches of engineering, naval architecture, agriculture, dyeing, textiles, and leather industries Between 1887 and 1917, some nineteen of these were established at Newcastle, Leeds, Sheffield, Birmingham, and Liverpool These often attracted a greater number of students than did the degree courses

Engineering studies became acceptable because of the pioneering efforts of King's College and University College London. At each civic university the first chair was either in civil engineering or in mechanics or mechanical engineering. Electrical engineering developed later in the century and many colleges appointed a lecturer in electrotechnics, some of which later became chairs: King's College (1890), Yorkshire College (1899), Liverpool (1903), Birmingham (1905), Newcastle (1907), and Sheffield (1917). Owens College, quite progressive in other branches of engineering, lagged behind in this, merely appointing a lecturer in electrotechnics in 1912.

The appointment of a professor at Liverpool in the new discipline of biochemistry stands out for its uniqueness, Sheffield, for instance, did not have a chair until 1945. Strictly speaking, though, the distinction of being first in this field perhaps ought to go to Birmingham, for in 1897 it created a Chair of Brewing and the Biochemistry of Fermentation. But what is so remarkable about the general development of chemistry education is the neglect of organic chemistry and the lateness in the recognition of physical chemistry as a subject in its own right. As late as 1900, there was only one full professor of organic chemistry (Owens College). Liverpool, Yorkshire College, and Firth College had lectureships in this subject and the chemistry of dyeing was included at Owens and Yorkshire College. As for physical chemistry, we can find only one appointment other than the chair at Liverpool up to the outbreak of the first world war and that was a special lecturer in the subject at Sheffield.

It may be that a fuller investigation would reveal perfectly valid reasons for all the inconsistencies and divergencies revealed in a study of the scientific staff of the civic universities. One single factor which would account for many of them is lack of finance, something all the colleges had in common. While college councils might wish to put in hand certain developments, the possibilities open to them in practice were often dependent on their benefactors and upon the local resources at their disposal. Thus at Leeds, the Clothworkers' Company donated £15,000 for the Textile Department and £2,500 for the Dyeing Department. At Sheffield, Sir Thorpe Mappin MP, a local cutler, gave £2,000 for the founding of a Technical Department, and the Drapers' Company gave £4,000 for a similar department in Nottingham, which also benefitted from the local coal-owners' guarantee of £300 a year for a Mining Department. At Birmingham, the local brewers gave £28,000 for the chair in brewing.

But while wealthy industrialists, manufacturers, and merchants were prepared to endow chairs, sometimes perhaps for reasons of prestige, the appointment of lecturers and demonstrators was financed out of general college funds Such funds were rarely in a healthy state – the accumulated debt at Liverpool in 1901 was £11,000 (23) – and this meant that junior posts were spread thinly At Liverpool in 1895, the ratio of junior to professonal posts was 1 6 to 1, many departments consisting only of a professor and one assistant That this was a general feature among the civic universities is evidenced by the fact that the ratio for all science and technology posts in 1894 was 1 7 to 1 (8)

The government played little part in the origins and development of the provincial civic universities, financial support was not forthcoming until 1889 when the first Treasury grant in aid was awarded Government resources were concentrated instead on the two London institutions – the Royal School of Mines and the Royal College of Science, in 1889, government aid to these colleges was £14,000, a sum almost equal to the total aid (£15,000) shared among all the civic colleges, and this was despite the pleas of industrialists that it was not in London that centres of science and technology should be placed but in areas such as Newcastle and Sheffield, in close proximity to the major centres of industry

In 1907 the two London colleges were amalgamated with the City and Guilds Central Technical College, founded jointly by the London Livery Companies and the Corporation of the City of London in 1884, to form the Imperial College of Science and Technology This co operative venture, involving the government, the London County Council, and the City and Guilds College, paid off handsomely for it quickly became the leading centre of science and technology and, by the outbreak of war, it had nearly 40 full or assistant professors Its impact can best be seen in the field of engineering for the number of candidates successful in the London Honours BSc in Engineering rose from a mere five in 1903 to 60 in 1910, and the College's contribution to this figure was thirty (35) Between 1903 and 1910, the City and Guilds College had a clear dominance over all other Colleges, producing 128 successes Its nearest rivals were University College London (43 successes) and King's College London (33 successes) The East London Technical College, formerly the Finsbury Technical College also founded by the City and Guilds, had 15 successes (35)

The subjects taught at the Royal College of Science prior to the amalgamation of the three colleges had been mathematics, physics, chemistry, and biology and, at the Royal School of Mines, geology, metallurgy, and mining The School of Mines was the first institution to include the last two subjects in its curriculum and lecturers were appointed in them in 1851 The Central Technical College concentrated on engineering and it became the Engineering Faculty of the Imperial College following the reorganization

Students at the three colleges were able to study for the BSc degree of London University but each of the colleges had established separate three or four-year courses leading to the award of college diplomas That at the the School Mines, the Diploma of Associateship of the Royal School of Mines (ARSM), was awarded to successful students after four years, students studied mining, metallurgy, and geology, but specialized in one of them In 1870, there were only seven successful candidates but numbers rose gradually and by 1910 there were thirty-eight (16)

The Royal College of Science provided a three year course in the sciences in which students specialized in one subject They were awarded the Diploma of the Associateship of the Royal College of Science (ARCS) As with the ARSM course, numbers completing the course successfully were few initially and the first success was not until 1882, but in 1910 there were 50 Diplomas awarded, 16 of them in chemistry (15) The Central Technical College, too, at the time of its foundation, inaugurated three year courses in civil and mechanical engineering, electrical engineering, and chemistry and these courses led to the award of the Diploma of Associateship of the City and Guilds Institute (ACGI) In 1910, there were no fewer than 85 diplomas awarded in engineering In addition to degree and diploma students, others labelled 'occasional students' were allowed to enter and study one or more special branches of science or technology (15)

Graduate scientists and technologists represented but a small fraction of all those who during the period under review received some measure of university training The graduates were the elite or the fortunate, or perhaps merely the 'fittest', for many students entered the universities on a full time basis after years of attending evening classes at technical colleges or the universities

Not all students entered for degree courses, other courses frequently being more popular Among those who did enter for degree courses, the number finishing the course and graduating was for a long time only a small proportion of those who began the course The 'drop-out' rate was high, large numbers at one stage of the course in one session followed by small numbers at the next stage in the following session

Scientific manpower

During the greater part of the nineteenth century there were few openings in industry for scientists in general, and opportunities for research, both at university and in industry, were rare This was less true of the chemical industry For instance, Brunner, Mond, and Company at Northwich and Joseph Crosfields' soap manufacturers at Warrington, were keen to employ scientists but were forced to rely on German-trained ones (5, 26) Their experience was shared by Edmund Muspratt at Widnes In 1870, when the total number of honours graduate chemists produced by English universities was 13, he was seeking a chemist for his Woodend works This he found none to easy

> Having so many new processes in hand I thought it advisable to engage a well educated chemist as head of the laboratory at Widnes It was difficult to find at that time a suitable man in England, and in Germany, owing to the war, which had taken so many young men for service in the army, it was difficult to find a young chemist willing to come to this country After some correspondence with Professor Knapp at Brunswick Polytechnic, I engaged a Dr Jurisch, who had been educated at Berlin (25, p 149)

For many, the opening up of the Dominion and South American countries offered more attractive prospects than were available in England and this accounted for the high 'braindrain' of trained manpower To some extent this was offset by an influx of trained scientists from the continental countries, particularly Germany With the establishment of the new civic colleges, the growth of technical colleges, and the gradual change in the attitude of the schools to science, opportunities in teaching and lecturing became increasingly available The attitude of industry changed also for, while earlier in the century there had been no very great demand for scientists, there was now a greater readiness to undertake organized research and this new attitude coincided with the production of new cadres of trained scientists One result of the availability of English trained manpower was that progressive firms such as Crosfields' of Warrington, who had earlier employed German trained scientists, were now able to replace them with men educated in the English universities

The scientific staff at Liverpool doubled between 1890 and 1900 and doubled again between 1900 and 1910 The year 1905 can be taken as the point of transition at which the level of the work at Liverpool became recognisably that of a modern university This conclusion can be taken to apply to other universities also and the process was accompanied by an upsurge of trained manpower from the universities

During the second half of the nineteenth century, the leading technological centre in England and the institution most likely to produce the managerial technologist and scientific research worker was the Royal College of Science and Royal School of Mines From a survey of the careers of 850 former students (4), it is possible to draw certain conclusions Of these 850 students, whose careers spanned a period of 40 years, only 170 (20%) had entered industry at some stage in their careers It is not unreasonable to assume that no other institution contributed as many Of those who spent some time in industry, the majority entered mining and brewing and frequently they held positions not in management or research but in the inspectorate Some 32% went abroad, either immediately on qualifying or at later stages in their careers, and 28% entered the teaching profession Some indications of research publications are available and from these it would seem that no more than 75 (9%) participated in research

A further source of information can be found in the Proceedings of the Institute of Chemistry for the year 1901 A survey of its 683 fellows brought replies from 343, the majority of whom were engaged in academic rather than industrial spheres No fewer than 66 had the degree of PhD, which indicates the strong connections between chemical training and the German universities (Only 38 honours chemists were produced by English universities in 1890) Thirty-three were on university staffs, 23 in technical colleges, and 84 were employed in laboratories of various description, these included the laboratory of Somerset House and public laboratories such as the railways and borough council laboratories Fifty of the Institute Fellows went abroad and an analysis of past students of the Liverpool University Engineering Society from 1885 to 1912 also reveals that there was a considerable 'brain drain' of graduates to the Dominions some 35% went abroad, which corresponds very closely to the 32% who went from the Royal College of Science

The numbers of fully-trained scientists and technologists in England fell far short of what was desirable in the last quarter of the nineteenth century In 1910, the number of university students of science and technology was about 3,000, whereas the corresponding figure in Germany was 25,000 (8, 19) On the one hand, there was a considerable wastage of scientific talents, on the other, there were too many inadequately trained scientists For every student who graduated, there were several only partially trained, either because they had failed the course or because they had been able to attend only night classes

One of the main objectives behind the creation of the civic universities was the training of the scientists and technologists the country needed The blame for not tackling this problem earlier may be attributed to industry for not creating a demand for scientists, to the ancient universities for paying too little attention to the physical sciences, and to successive governments for their failure to establish an efficient unified educational system It is certainly true that the intake of scientists into industry was not very great but it may well have been that many firms had every wish to employ scientists but were unable to because of the shortage of men of the highest calibre It seems, therefore, that, while industry should not be entirely exonerated, the major portion of blame should fall on successive governments, for the civic universities were left to struggle on as best they could facing immense difficulties in their attempt to achieve their main objective More government money at an earlier stage, improved primary and secondary systems of education, and a national system of scholarships along the lines of the Whitworth Scholarships could have eased their task Neither the Devonshire nor Samuelson Commissions (11, 12, 13) produced a cogent analysis of England's long-term needs for scientific manpower The picture that emerges from this survey of the civic universities reflects an absence of analysis and of planning, at the core of the problem was the lack of a national blue-print based on national objectives The Imperial College of Science, in which the government played a full part, showed what could be done if the problems were tackled in a systematic way The picture in England was in total contrast to that found in Germany

SCIENTIFIC EDUCATION IN GERMANY

The German universities, unlike their English counterparts, were state sponsored institutions, being a direct responsibility of the Minister for Education They had their origins in the new movements of thought which swept Europe in the fourteenth century By the beginning of the nineteenth century, some 20 universities had been founded throughout the states which later became unified to create the modern Germany These universities were based on a four-faculty structure embracing law, medicine, theology, and philosophy, the last of which was a late addition being first established at Gottingen in 1737 It was through the philosophy faculty that the German universities attained their greatest eminence, this was attributable in large part to the role the universities played in fostering the study of science, which formed part of the philosophy faculties In the rapid expansion of the universities that occurred between 1820 and 1900, whilst student numbers rose five times, students in philosophy faculties increased by a factor of ten

At a time when German morale was low, following defeat at the battle of Jena, Alexander von Humboldt (1769-1859) conceived the salvation of the German nation as coming from the universities through a combination of teaching and research Influenced by the work of Joseph Louis Gay-Lussac in Paris, von Humboldt did much to introduce empirical science into the philosophy faculties of the German universities In these universities, theology, law, medicine, and philosophy were all held to be treated 'scientifically' and to form the universal sum of human knowledge This broad concept of science was termed *Wissenchaft* and was far removed from the English and French use of the word science, meaning empirical or 'exact' science Humboldt spread the ideas and methods of French science in Germany Jons Jakob Berzelius exerted a strong influence too by his writings but the most significant contribution was made by Justus von Liebig (1803-1873), one of Gay-Lussac's first students, when in 1826 he established a chemistry laboratory at Giessen Chemistry, especially organic chemistry (von Liebig's special contribution) was to become the pre-eminent German science Von Liebig's laboratory became a world famous international training school and a model for others established later in the century

The universities

German universities during the nineteenth century were noted not only for the excellence of their scholarship but also for the lavish sums spent on them and the high status and earning power of their professors who, in addition to salaries, received up to £750 in fees depending on their reputation The most generous of the states was Prussia which in 1805 spent £15,249 on the universities – a sum exceeding the first grant to English universities in 1889 By 1880, Prussia was spending £350,000 on its six universities Berlin University seems to have been the German university best supported by any of the states, in 1876, it received 91% of its income from state sources The corresponding figures for Halle and Heidelberg were 65% and 41 percent The average figure for all the universities was 71%, in 1899 it was 69 percent (9)

The excellence of the German universities must be seen of course against the background of the remainder of the educational system, in particular the schools Like the universities these too were state institutions, established only with the state's knowledge and consent Patronage by church or private persons was rare The foundations of a highly structured and well organized educational system was first laid in Prussia by von Humboldt when he was placed at the head of the Prussian Education Department in 1808 This became the model for the other states In 1817, the Department became a separate Ministry and central control for the schools was vested in the Minister but his jurisdiction over schools was exercised through local departments For administrative purposes Prussia was organized into eight provinces, the provinces in turn being split into 26 government districts Each province had a school board and each district a government district board

It was not only a matter of organization and administration, von Humboldt gave effect to the meritocratic principle introducing rigorous tests for intending schoolmasters and putting the *Abiturientenexamen*, a secondary school leaving examination first introduced in 1788, on its present day footing Taken in conjunction with the widespread provision of schools at different levels, elementary, middle, and secondary, this ensured a steady supply of well-educated students with a sound theoretical knowledge into the German higher-education system

Nothing approaching the extent of provision nor the degree of organiz ation of the Prussian system was to be found in England until 1902 There was no doubt in the minds of a deputation from the City of Manchester visiting Germany in 1896 that the key factor in Germany's rise to industrial eminence lay in its school system

> It is by no means a difficult matter to trace to the influence of the schools and the system of education generally, the improvement which has marked the manufacturing progress of Germany It is high time the effort was made in this country to give to our youth the educational advantages which are enjoyed by their rivals abroad (22, p 18)

The Samuelson Commission set up to inquire into technical instruction in England examined the school system in Germany In its report, it stated

> Secondary instruction of a superior and systematic kind is placed within the reach of the children of parents of limited means, to an extent of which we can form no conception in this country (12, Vol 1, p 23)

The same lavish expenditure that one observes in regard to the German universities is found applying to the school system Again, this was particularly true in Prussia But is was not merely a question of setting aside certain sums of money, money was allocated according to pre determined needs as Dr Rose recorded

> The Prussian Education Ministry maintains that state aid must be regulated by the needs of various localities and must not be simply a question of the even distribution of a certain amount laid aside for educational purposes (9, p 24)

The technical high school

Universities formed only a part of the German higher-education system, which also encompassed trade schools, technical high schools, and specialized higher institutes of technology In contrast to the English system, technical studies were to be found not in the universities but in the technical high schools These *technische Hochschulen* were created between 1840 and 1890 by converting at enormous cost small trade or technical schools established earlier in the century The first technical high school at Karlsruhe established in 1867 had its origins in 1825 when it was modelled on the French *ecole polytechnique* The one at Berlin founded as a technical school in 1821, became a trade and building academy in 1871, and ultimately a technical high school in 1881 The technical high schools at Darmstadt (1883) and Stuttgart (1870) were founded originally as trade schools in 1836 and 1840 repectively Between the formation of Karlsruhe in 1867 and Dresden in 1890, nine technical high schools were estabhshed – Aachen, Karlsruhe, Darmstadt, Dresden, Hanover, Berlin, Stuttgart, and Munich

In most cases, it was merely a question of converting or extending existing premises, albeit at considerable expense to the authorities, in other cases, entirely new buildings were erected Stuttgart, founded as a Trades School in 1829, extended its buildings in 1879 at a cost of £75,000 New buildings were provided at Dresden (1875), Hanover (1879), and Aachen (1870), where a new chemistry laboratory was built at a cost of £45,000 The Munich Technical High School cost the state £157,000, that at Hanover £350,000 and a new building at Berlin £450,000 The running costs, too, were largely provided by the state, the school at Berlin, for instance, received 90% of its income from the state in 1876 The actual extent of state support varied from one school to another In 1876, it ranged from 25% to 93 percent

It appears that the motive underlying this vast expenditure was quite simple The technical high schools, according to the Samuelson Commissioners, were to impart

> a scientific training with its practical applications so that by this means a body of men might be educated in such a way as to make it possible for continental states to compete with the workshop trained engineers of England (12, Vol 1, p 192)

The technical high schools were not without their critics, some of whom claimed that the syllabus was too broad and candidates were being examined in too many subjects To offset this, Prussia in the 1890s replaced the customary diploma course with a new one leading to the award of *Doktor-Ingenieur*, set and marked by a state-examining body As well as a full range of science and engineering disciplines, the technical high schools included special subjects in their curriculum – naval architecture (Berlin), mining (Aachen), forestry (Stuttgart), and agriculture (Munich)

Whatever the demerits and deficiencies of the technical high schools in German eyes there was nothing comparable to them in England and any assessment of them must be set against the relative neglect of technical instruction in English universities and the difficulties encountered in establishing such studies within them By 1900, there were over 13,000 students attending the technical high schools which, without exception, had highly qualified staffs (9, p 25) There were over 4,000 students in attendance at Berlin alone in 1903 This school, *Konigliche Technische Hochschule* at Charlottenburg, was perhaps the prize among the technical high schools It was a state institution under the direction of the *Kultur-minister* (or Minister for Ecclesiastical, Educational, and Medical Affairs) The school provided through a four-year course a specialized training in industrial subjects founded on a preliminary scientific education In contrast to England, students came to the school well prepared having previously been required to attend a gymnasium for nine years and to pass the rigorous and demanding school leaving examination Students at the school in 1903 included architecture (739), civil engineering (689), mechanical engineering (1499), electrical engineering (321), naval architecture (259), marine engineering (123), chemistry (181), metallurgy (180), and some officers and engineers from the Navy (cf 6) The total complement of staff, including professors, *Privatdozenten*, engineers, lecturers, and assistants amounted to 402 There were 89 professors, 13 in chemistry alone

The universities and technical high schools were the apex of a scheme which provided for the entire higher and further education needs of the German people The aim, as pointed out in a London County Council report in 1914, was to build a great industrial nation 'partly by the thorough training of the leaders as experts, partly by the training of the middle grade workers as thoroughly accurate and careful managers, and partly by the training of all grades of workmen and mechanics as skilled crafts-men' (21, p 1) The same view was expressed in another way by Mr Blair, Education Officer, London County Council in his introduction to the London County Council report Germany , he said 'is systematically training the whole nation in different ways for their different spheres' (20, p 1) At the upper end, there were specialized higher trade schools in weaving at Berlin, Chemnitz, Krefeld, and Mulhausen Similar schools existed for building, mining, and industrial art Long before the end of the century, there were compulsory continuation schools catering for the 14 to 18 year old age group Employers of labour were obliged by law to allow their employees to attend these schools or otherwise pay a fine The system of apprenticeship as practised in England was unknown in Germany There apprenticeship was dealt with by statute and the apprentices were compelled to attend continuation classes for six to nine hours a week At all levels, German education was characterized by a systematic thoroughness and zeal

Chemistry and engineering

The universities, technical high schools, and higher institutes of technology created for German industry an elite corps of highly trained scientists and technologists Matthew Arnold, after his visit to the continent in the mid-1860s, was of the opinion that

> it is in science that we (i e , in England) have most need to borrow from the German universities (2, p 152)

But he also recognized that the root cause of the trouble in England lay in the absence of an organized system of secondary schools and in the lack of attention given to scientific education in such schools

> Our dislike of authority and our disbelief in science have combined to make us leave our school system to take care of itself as best it could Under such auspices our school system has done and does nothing to counteract the indisposition to science which is our great intellectual fault (2, p 198)

Once the spirit of exact science had become diffused into the German universities they were prepared to look elsewhere and the desire to learn from all quarters characterized the early decades of the resurgence of German science The fruits of this resurgence were seen most clearly in chemistry Chemical instruction in the German higher education system was the object of much study by English observers during the second half of the nineteenth century and many reports were produced by visiting English deputations

Although the foundation for German chemistry, particularly organic chemistry, was laid by Liebig at Giessen, chemistry was being taught during the eighteenth century at Jena, Marburg, and Göttingen and there were chemistry laboratories for the use of students prior to Liebig He broke new ground by providing in his laboratory a systematic training in qualitative and organic analysis It quickly became an international training school attracting students from many parts of the continent For English chemists it was the most advanced form of chemical instruction then available Others followed Liebig's example and during the period 1830 to 1870, Liebig, Hofmann, Bunsen, and Kekulé were responsible for training up to 60 students at a time at Giessen, Munich, Heidelberg, Berlin, and Bonn

James Muspratt, who is credited with being the 'father' of the English heavy chemical industry, sent all four of his sons to be educated at Giessen in preference to sending them to English university-type establishments Other distinguished English chemists to be educated at German universities were Sir Edward Frankland (Marburg and Giessen), later Professor of Chemistry at Owens College Manchester, Sir Lyon Playfair (Giessen), later Professor of Chemistry at Edinburgh University, Sir William Ramsay (Heidelberg and Tübingen), later Professor of Chemistry at University College London, and Sir Thomas Edward Thorpe (Heidelberg and Bonn), later Professor of Chemistry at Yorkshire College Leeds

During this period the German chemical industry became the envy of every other industrialized country, being particularly ahead in the field of artificial dyes and fertilizers It owed its success to the extensive number of highly trained chemists produced by the universities and technical high schools According to Haber

> A steadily increasing flow of well trained chemists contributed materially to the rapid development of the German chemical industry in general and the dyestuffs industry in particular Scientific education in Germany and its abuse or neglect in other countries played an important role in the spread of industrialisation (14, p 71)

Shadwell claimed that

> manufacture of chemicals alone has become one of Germany's greatest assets valued at £50 million a year – but secondary applications of chemistry were still more important, including metallurgy, dyeing and oils (32, p 426)

At one time it was estimated that there were 4,000 highly trained works-based chemists in addition to private chemists, lecturers, and teachers in Germany (21), some two thirds of the world's chemical research output came from that country (9) A factor which helped in this, in addition to extensive facilities and laboratories, was the wide range of qualified staff to be found in the institutes of higher education Berlin University alone had a staff of 36 in 1895 and there were no fewer than eleven professors of chemistry despite the fact that the Technical High School also had six In addition to covering the conventional areas of inorganic, organic, and physical chemistry, there were full time professorships in chemical technology, metallurgy, electro-chemistry, and photo-chemistry, and qualified lecturers taught the chemistry of food, of oils, and of agricultural chemistry This division of responsibilities among a variety of professors was a feature which attracted the attention of the members of the Royal Commission on Technical Instruction on their visit to the continent

> This distribution of the teaching amongst professors, each of whom is specially conversant with the details of some portion of his subject, is in striking contrast with the English system, in which the instruction is generally placed under the direction of one professor (12, Vol 1, p 192)

The large number of professors attached to each Department in the universities and technical high schools was 'yet another indication of the ample supply of highly educated men available as teachers always to be found in Germany,(12, Vol 1, p 192)

The disbelief in theory in England was nowhere more evident than in the training of engineers In Germany, advanced and theoretical scientific instruction was the *sine qua non* of the training of the best engineers It was in engineering training that the differences between England and German practices were most marked In England, it was based on a system of apprenticeship to a practising engineer with the student paying a premium

> Young Englishmen and their parents crowd the doors of the offices and workshops, offering premiums of £300 or £500 for the mere permission to pass three years inside the magic gates, which must be passed to gain an entrance into the profession (17, pp 200 201)

The general view in England was that theoretical knowledge was not 'absolutely essential' This could be picked up by 'night-school' study, which after long arduous days at the factory bench boiled down to a system described as 'survival of the fittest' and 'throw enough mud and some of it will stick' As one leading engineer put it to Matthew Arnold

> Our rule of thumb has cost us dear already and is probably destined to cost us dearer still Our engineers have no scientific instruction and we let them learn their business at our expense by 'rule of thumb' but it is a ruinous system of 'blunder and plunder' (2, p 198)

The apprentices were not always placed in the charge of someone competent and willing, boys were allowed to pick up the technology of their trade more or less as they pleased and according to their degree of motivation

> Young men at the age of 18 enter the office of a civil engineer Usually few questions are asked as to previous training – the pupil is a sort of nuisance in an office, only tolerated in consideration of the fee which accompanies him (17, p 201)

Germany, in contrast, established a quite rigorous system of theoretical instruction to produce a corps of state-trained engineers *(Baumeister)* After a successful gymnasium education and a year spent at a state construction office, a student was allowed to enter the government school of construction in Berlin (the *Königliche Bauacademie*) where he spent two years studying science, engineering, and architecture At the end of this, and if successful in the state examination, he spent three years in practical employment This was followed by two further years of study and a second state examination Thus, the complete education of the government engineer occupied eight years from the time of his leaving school

In England, it was not fashionable for boys to go from good schools to study engineering A study of a representative selection of the leading middle-class schools (Harrow, Eton, Rugby, Mill Hill, Marlborough College, and Dulwich College) during the period reveals that less than 4% of those leaving school entered the engineering profession (30) Furthermore, those who did so were ill-equipped to pursue such studies 'Students enter technical institutions ill-prepared and at least one year has to be devoted to instruction which ought to be secured beforehand' (18, p 166)

The British pioneered electrotechnics, yet by 1913 the output of the British electrical industry was only a third of that of the Germans and its exports barely a half By the outbreak of war Britain was short of Khaki dye, acetone for explosives, and magnetos for transport, as Germany had become the chief source of supply (1)

Clearly it could not be denied that there had been a decline in the rate of increase of industrial production compared to Germany To attain this state of affairs Germany had invested heavily in education, the central state expending vast sums of money throughout the second half of the century Nowhere was this more evident than in the case of chemical education Dr Frederick Rose attempted to show the extent to which the German chemical industries benefitted from the sums expended by the German states on chemical instruction

> The figures show that the Prussian state, in spite of the expenditure already incurred and the leading position attained by the chemical industries, is far from regarding the present admirable means of chemical instruction as adequate for future contingencies but is at all times prepared for further lavish outlay should future developments reveal this necessity (10, p 9)

CONCLUSION

Following the Great Exhibition of 1851, Lyon Playfair (later 1st Baron Playfair) in a speech at the setting up of the Government School of Mines uttered the following warning, 'As surely as darkness follows the setting of the sun, so surely will England recede as a manufacturing nation, unless her industrial population become much more conversant with science than they are now' (29, p i) History was to bear out Playfair's prediction At the time of his prognostication, Germany held a lowly position in industrial production, by the end of the century she had attained ascendancy in a number of fields (34)

We have already noted that the impetus to the rapid expansion of university education in England in the second half of the nineteenth century was provided by the poor relative performance of British industry after 1870 and the fear of German competition In the twenty year period 1860 1880, the annual percentage rate of industrial growth in the United Kingdom was 2 4, whereas in Germany it was 2 7, for the following twenty year period, the respective figures were 1 7 and 5 3 (27) In the steel industry, our production was surpassed by that of the United States in 1886 and by Germany in 1893 The British chemical industry in 1913 accounted for only 11% of world output as against 24% by Germany which also exported twice as much as did Britain (26)

Finance was one aspect of the problem (9) Matthew Arnold saw other factors as inhibiting advance in England

> There are two obstacles which oppose themselves to our consulting foreign countries with profit One is our notion of the state as an alien, intrusive power in the community, not summing up and representing the action of individuals but thwarting it the other is our high opinion of our own energy and prosperity (2, p 20-21)

In nothing did England and Germany differ in the nineteenth century as much as in their attitude to education It was not only that attitudes differed among those in positions of power and responsibility, favourable attitudes were widespread in German society and found at all levels Mr Robert Blair, Education Officer to the London County Council, introducing a report on Technical Education in Germany and France summarized the situation in the following terms

> It will be observed how in Germany the state, municipality and the employer have all come to believe in education of all types The organised efforts of the state and municipality are reaching every child in a way that would hardly be credited in England (where) we still follow the plan of *laissez-faire* or go as you please (20)

This was the generally held view of contemporary observers Mathew Arnold came to the same conclusion on his visit to the continent in 1868 'We have nearly all of us reached the notion that popular education is the state's duty to deal with Secondary and superior instruction many of us still think should be left to take care of themselves' (2, p 186)

Arguments have raged as to the effects of the higher-education systems of the two countries on their respective economic and industrial positions The majority of contemporary observers firmly believed that the key to Germany's success lay in her higher-education system and pointed to the inadequate financial resources, the lack of planning, and the neglect of research that characterized the British system Professor Payne has written that 'the whole complex of circumstances that produced British pre eminance before 1873 was fortuitous' (28, p 51) It was, he argued, historically determined, the outcome of a number of favourable geographic, commercial, and technological factors Education in England played no part in the attainment of this industrial pre-eminence as the favourable circumstances disappeared one by one Some present-day writers argue that improvements in higher education would only have had a marginal effect on industrial production For instance, Michael Sanderson claims 'that the connection between higher education and industrial competitiveness was not always so close as the Victorians sometimes thought' (31, p 34) In connection with the steel industry, Temin has argued that given that Germany and the United States could assemble the materials for steel making as cheaply as we could and given tariffs and their large markets, then slight relative differences in the quality or cost of producing steel or of the levels of higher scientific education became irrelevant (33)

However, it is our contention that the state of affairs suggested by the evidence put forward in this article did have a deleterious effect on British industry and conferred a corresponding benefit on German industry In the final analysis it amounts to no more than a statement of strong belief, for the relationship between education and industrial growth is inextricably complex Support for our view however is found in Professor Margaret Gowing's assertion that a small group of historians 'do accept that Britain's failure in the nineteenth century to develop the educational system essential for national efficiency was a main cause of industrial decline I am on their side' (7) As for Germany, Professor Musgrave considers that that country 'seems to have come nearer in educational terms to what was economically appropriate He concludes that while the nature of the educational system probably did not play a large causative role in contemporary British economic ills, it probably did play some part in 'Germany's remarkable leap into the industrial world' (24)

REFERENCES

1 ALLEN G C *The British disease* London Institute of Economic Affairs 1978

2 ARNOLD M *Higher schools and universities in Germany* (2nd ed) London Macmillan 1892

3 BELLOT H H *A history of University College London, 1826 1926* London University of London Press, 1929

4 CHAMBERS T G *Register of associates and old students of the Royal College of Chemistry the Royal School of Mines and the Royal College of Science* London Hazell Watson & Viney 1896

5 COHEN J M *Life of Ludwig Mond* London Methuen, 1956

6 DALBY W E The education of engineers in America Germany and Switzerland *Proceedings of the Institute of Mechanical Engineers* 1903 281 349

7 GOWING M Science technology and education England in 1870 The Wilkins Lecture *Notes and Records of the Royal Society of London* 1977 *32*(1) 71 90

8 GREAT BRITAIN EDUCATION DEPARTMENT *Reports from university colleges participating in the grant of £15 000 made by parliament for university colleges in Great Britain* London Her Majesty s Stationery Office 1894

9 GREAT BRITAIN FOREIGN OFFICE Chemical instruction and chemical industries in Germany Report by Dr Frederick Rose, H.M Consul at Stuttgart, Diplomatic and Consular Reports Miscellaneous Series No 561 1901

10 GREAT BRITAIN FOREIGN OFFICE Chemical instruction and chemical industries in Germany Supplementary report Diplomatic and Consular Reports Miscellaneous Series No 573 1902

11 GREAT BRITAIN ROYAL COMMISSION ON TECHNICAL INSTRUCTION (Samuelson Commission) *First report* London Her Majesty's Stationery Office 1882

12 GREAT BRITAIN ROYAL COMMISSION ON TECHNICAL INSTRUCTION (Samuelson Commission) *Second report* London Her Majesty s Stationery Office, 1884

13 GREAT BRITAIN ROYAL COMMISSION ON THE ADVANCEMENT OF SCIENCES AND SCIENTIFIC INSTRUCTION (Devonshire Commission) *Reports* London Her Majesty's Stationery Office 1872 1875

14 HABER L F *The chemical industry during the nineteenth century A study of the economic aspect of applied chemistry in Europe and North America* Oxford Clarendon Press 1958

15 IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY *Calender 1910*

16 IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY *Calender 1918*

17 INSTITUTION OF CIVIL ENGINEERS *The education and status of civil engineers in the United Kingdom and in foreign countries* London Institution of Civil Engineers 1870

18 INSTITUTION OF CIVIL ENGINEERS Education and training of engineers Report of a Committee appointed by the Council of the Institution of Civil Engineers, 1903 *Proceedings of the Institution of Civil Engineers*, 1905-06, *166*, Pt 4 159 182

19 KUKULE, R, & TRUBNER K *Minerva, Jahrbuch der Gelehrten Welt* Berlin Trübner 1910

20 LONDON COUNTY COUNCIL Introduction by Mr Robert Blair to *Trade and technical education in Germany and France* Report by Mr J C Small Organiser of Trade Schools for Boys 1914

21 LONDON COUNTY COUNCIL *Trade and technical education in Germany and France* Report by Mr J C Small, Organiser of Trade Schools for Boys, 1914

22 MANCHESTER CITY OF TECHNICAL INSTRUCTION COMMITTEE Report of the deputation appointed to visit technical schools institutes and museums in Germany and Austria 1897

23 MUIR R *A plea for a Liverpool university* Liverpool Tinling, 1901

24 MUSGRAVE, P W The labour force Some relevant attitudes In G W Roderick & M D Stephens (Eds), *Where did we go wrong? Industrial performance education and the economy in Victorian England* Lewes, Sussex Falmer Press, 1981

25 MUSPRATT, E K *My life and work* London John Lane 1917

26 MUSSON A E *Enterprise in soap and chemicals* Manchester Manchester University Press, 1965

27 PATEL, S J Rates of industrial growth in the last century 1860-1958 *Economic Development and Cultural Change* 1961 *9* 316-330

28 PAYNE P L *British entrepreneurship in the nineteenth century Studies in economic history* London Macmillan, 1974

29 PLAYFAIR L The study of abstract science essential to the progress of industry *British eloquence Literary addresses second series* London Griffin, 1855

30 RODERICK G W & STEPHENS M D Scientific studies in the public schools and endowed grammar schools in the 19th century Evidence of the Royal Commissions *Vocational Aspect of Education* 1971 *23* 97 105

31 SANDERSON M *The universities and British industry 1850 1970* London Routledge & Kegan Paul 1972

32 SHADWELL, A *Industrial efficiency A comparative study of industrial life in England Germany and America* London Longmans Green, 1906

33 TEMIN, P The relative decline of the British steel industry, 1880-1913 In H Rosovosky (Ed), *Industrialization in two systems* New York Wiley, 1966

34 UN ECONOMIC COMMISSION FOR EUROPE *Growth and stagnation in the European economy* Geneva UN Economic Commission for Europe, 1954

35 UNIVERSITY OF LONDON *Calender 1910*