Emergence of Science and Engineering as Elite Subjects in UK

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The 20th century saw a huge expansion of higher education in all countries and at all levels. In universities the past 50 years have been devoted to growth, expansion and widening access. Economically advanced countries have now achieved mass higher education, embracing upwards of 40% of young people. The benefits are evident: aspirations for access have become entitlements, for women as well as men; and democratic societies enjoy the benefit of educated workforces and electorates. Over-riding all else, it is seen that growth of higher education has been accompanied by affluence and improved qualities of life.

Politics and economics have been the driving forces for these changes; and inevitably, the changes have been instituted by governments, not universities, It is true that universities identified the link between knowledge and affluence but it was a political response to the "white heat of the technological revolution" that led to action. This linked education, employment and the economy as a single vital element in state affairs. As is normal, politically inspired government policies yield diverse results even when shared by differing political parties. Justification of increased support from taxation for education permitted the developments; but equally, it encouraged the fallacy that the needs of the market determine provision of education.

The results are impressive. Huge expansions in participation, numbers of graduates, size and numbers of institutions have been achieved. There are increases in the range and diversity of academic programmes, in patterns of study, and in the quantity and quality of research. Equally impressive have been the increases in overall costs. The influence of developments in the United States has been particularly important, especially in the statistics they have yielded: participation rates of over 60%, with 16 million students in 3,000 institutions and annual expenditure of $130 billion. But the statistical role model this has provided has not extended to structural developments in the national systems of other countries. It may indeed be that the very absence of a national system in the United States has allowed development of their rich diversity of higher education institutions. They range, in the terminology of the Carnegie classification, from Research Universities, Doctoral Universities, and Comprehensive Universities, through 4-year Colleges and Liberal Arts Colleges to 2-year and Community Colleges. This very diversity has facilitated and

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expanded with mass higher education in a way that is not echoed in other countries. Moreover it has also accommodated the outcomes of simultaneous development of mass secondary education in a way not found elsewhere. One consequence is that this has allowed the United States to combine one of the less successful systems of secondary education with the world's most successful system of higher education.

In other countries, mass higher education has been developed within structures that had previously provided elite higher education. New collegiate institutions have been added subsequently to the expanded university systems but with a primary objective of increasing capacity for traditional degree courses. In the UK, the polytechnics were established in the 1960's, with the intention of meeting the perceived need for more technologists and applied scientists: they fulfilled expectations of rapid growth, but only by responding to student demand for courses in the social sciences. In essence they sustained the tradition of the English 3-year undergraduate degree. By the 1990's they had become universities: and by that time both they and the established universities had broadened the pattern of higher education courses, through establishing courses in new subject areas, expanding provision for sub-degree 2-year diploma courses, and by hugely expanding opportunity for part-time study.

The statistics (**Table 1**) illustrate the scale of these changes. Over a period of 40 years, the total number of undergraduate students has increased by a factor of 11 (i.e. 1100%). This is substantial but in fact it is less significant than three other statistics. The number of women in higher education, little more than a quarter of the total in 1966, is now a majority; the number of part-time students has risen from 2% to 34% - one in every three students is now part-time; and the number of students pursuing sub-degree courses has risen similarly from 2% in 1966 to 30% in 2003. There is quite a close relationship between the number of part-time students and the number of sub-degree students. The increase of women students represents an important social, cultural and economic advance;

Table 1. Undergraduate students in higher education. (UK)

	1966-7	2003-4	
All undergraduates			**Increase**
Full-time	155,478	1,069,210	
Part-time	2,793	547,020	
Total	158,271	1,616,230	x 11
First degree courses			
Full-time	153,354	939,890	
Part-time	2,362	108,940	
Total	155,716	1,048,830	x 8
Sub-degree courses			
Full time	2,124	129,320	
Part-time	431	438,080	
Total	2,555	567,400	x 200
Full-time Students	98%	66%	
Women Students	28%	58%	
Sub-Degree Students	2%	30%	

(UGC, 1969; HESA, 2005)

educationally it has modified the balance between courses; but institutionally it has not caused any major structural change. The increases in part-time students and sub-degree courses constitute the profound structural effects of mass higher education.

In England, the characteristic pattern of first-degree courses has been the 3-year "honours" degree with specialization in a single subject – history, economics, engineering, chemistry. A conventional pattern has been to study three subjects in the first (freshman) year, two in the second year and one in the third and final year. So in chemistry, a common pattern would be for students to study chemistry, physics and mathematics in the first year, chemistry and physics (as a minor subject) in the second year, and chemistry alone in the third year.[1] The level of attainment in the special subjects of the 3-year honours degrees is widely recognized as at least equivalent to that found elsewhere from 4-year undergraduate programmes. Achieving this standard is implicitly dependent on three conditions.

(a) Necessary provision of general education has been achieved at completion of secondary education.
(b) Basic principles of the subjects to be studied at university will have been covered in secondary school.[2]
(c) University courses are intensive throughout the 3 years and require full-time study.[3]

There is abundant evidence to indicate that currently it is no longer possible to assume that any of these conditions is satisfied.

The numbers of part-time and sub-degree course students within the higher education system indicate that the institutions have needed to change fundamentally their academic programmes. The number of full-time students now combining study with part-time employment is large. But as a driving force for change, the influence of mass secondary education is of at least equal significance. Before the 1970's, the route to university lay through the "grammar schools", selective secondary schools with academic

Table 1a. Postgraduate students in higher education. (UK)

	1966/1967	2003/2004		
	Total	Total	UK	Overseas
Full-time Students	31,894	220,395	113,635	106,760
- research	18,112	56,650	30,385	26,265
- courses (higher degrees)	13,138	116,745	42,515	74,235
- courses (other)	644	47,000	40,735	6,260
Part-Time Students	13,098	303,435	253,635	49,723
- research	5,540	54,190	37,260	16,938
- courses (higher degrees)	4,252	145,950	120,060	25,885
- courses (other)	3,143	103,295	96,315	6,900

Note. In 1966/1967 there were 9,169 full-time and 1,573 part-time overseas students.

educational programmes. To remove the social inequalities implicit in selection, this system has been progressively changed to one of non-selective, "comprehensive" secondary schools. This has opened the way for many more pupils to obtain qualifications enabling them to enter higher education (though it has failed the expectation that it would remove the social imbalance of a preponderance of students from the more affluent families in higher education). The social benefit of comprehensive secondary education has had educational costs. Larger numbers, wider spreads of ability, and a pervasive youth culture increase the burdens on teachers: they contribute to a perception of lower academic standards in the schools. While parents and government attach great importance to success in examinations, opportunities for general education and education in depth are increasingly constrained.

The result, as seen in the universities, is a necessity to include more peripheral and introductory aspects even of the special subjects – whether it be differential equations and calculus, mediaeval history, or introductory organic chemistry. This provides universities in the UK with the same problems that are regularly identified in Japan and well documented in the USA, of needing to complete the process of secondary education before higher education can begin (see e.g. Clark 1997).

For some subjects – notably the physical sciences and mathematics – the problems are even more acute. Four further limiting aspects can be seen.

(a) They are unpopular by virtue of a reputation for being difficult and from a cultural attitude that identifies them as environmentally threatening.
(b) They are expensive, which imposes restrictions on numbers and on the way they can be taught: practical laboratory work is dangerously expensive.
(c) There is a shortage of well-qualified teachers. Substantial minorities of specialist teachers of the sciences and mathematics have no degrees in these subjects.[4]

Table 2. GCE A-level entries and results (UK). (DES, 1968; DfES, 2003)

Subject	Entries	Passes			
		Grades A-C	%	Grades A-E	%
1966/1967					
Biology	31,800	10,600	33%	21,200	67%
Chemistry	40,500	13,800	34%	27,900	69%
Physics	54,500	17,800	33%	36,900	68%
Mathematics	69,700	23,300	34%	46,300	66%
All Entries	490,000	165,600	34%	335,600	69%
2001/2002					
Biology	60,600	37,600	62%	54,500	90%
Chemistry	45,700	32,400	71%	42,500	93%
Physics	40,400	27,500	68%	37,200	92%
Mathematics	73,400	52,800	72%	65,300	89%
All Entries	871,700	584,000	67%	828,000	95%

Note (i) Percentages calculated as proportions of entries.
(ii) Figures for 1966/1967 estimated for UK from published data for E & W. (DES 1968).

(d) There is a gender barrier that constrains the number of girls electing to study mathematics and the physical sciences.[5] In biological sciences the number of boys is similarly constrained.

The consequence is that only school pupils who are both motivated and fortunate are likely to be able to pursue these subjects to the level of the school leaving examination (GCE A-level) and to satisfy entry conditions for the universities.

The GCE A-level examination takes place at the completion of secondary education. Comparison of the results of the GCE A-level examinations for 1966/1967 and 2000/2001 reveals the extent of change (**Table 2**). Reflecting the increase in numbers of pupils, numbers of entries for the examination have almost doubled. But while the proportion being examined in biology has remained constant, in the physical sciences and mathematics it has fallen dramatically. Moreover, the proportions of those being examined and gaining the so-called "good grades" (A–C) has also doubled. These are the grades normally considered appropriate for entry to specialized university courses. The proportion achieving these grades now is similar to the proportions achieving grades A-E 35 years ago. Interpreting these dramatic changes is not simple: the syllabuses and structures of the examinations have changed over time. A large perturbation derives from a politically inspired shift from normative to criterion-based determination of grades. Consequently, some argue that the greater success rates – which increase year by year – and greater proportions of high grades reflect more dedicated study by pupils and more effective teaching; others see the results as indicating a "dumbing-down" of the examinations through relaxed syllabuses and lowered standards.

One obvious consequence of the developments derived from mass secondary education is that the great increase in undergraduate numbers in the universities is not distributed uniformly over all subjects. In particular, numbers of students studying the physical sciences, mathematics and engineering have shown

Table 3. First year Full-time Undergraduates (First Degree Courses) (UK)
(UGC, 1969; HESA, 2005)

Subject	1966/1967		2003/2004	
Biology	1,258	2.4%	7,075	2.1%
Chemistry	2,592	4.9%	3,315	1.0%
Physics	2,001	3.8%	2,840	0.8%
Mathematics	2,688	5.1%	5,480	1.6%
Engineering	9,283	17.6%	20,870	6.2%
All Students	52,756	100%	337,680	100%

much smaller increases (**Table 3**). While the gender barrier precludes these subjects benefiting from the general increase in women students, their limited growth actually indicates a significant reduction in popularity with men students.

There have been significant structural consequences for the universities. From the 1960's when Faculties of Medicine, Science and Engineering provided almost 60% of the students, they contribute now no more than 40%. Within departments the effects have been profound – and to a large extent, not predicted. Despite limitations of student numbers, demand for science and engineering graduates has been sustained; and commercial and governmental expectations have led to unprecedented resources and opportunities for development. Yet in the universities, departments of science and engineering have been closed and continue to close. Moreover, while provision for mass higher education has caused courses to be restructured to accommodate non-traditional and less well-prepared students, science and engineering departments have chosen to extend the academic depth and rigour of their courses.

Closure of Departments.

From a situation in the 1960's, when departments of chemistry and physics were considered essential in all new (as well as existing) universities, they are now found in less than one-third of the universities. Yet this is not necessarily an indicator of a reduction in provision for teaching these subjects. For instance, as an enabling subject, chemistry is taught in greatly increased numbers in departments of biochemistry, pharmacy, environmental science, materials science and (most recently) in forensic science (**Table 4**). For chemistry departments, growth in these now popular subject areas provides serious competition for students qualified with good grades at A-level. Traditionally students seeking entry to Faculties of Engineering would have achieved good grades at A-level in chemistry, physics and mathematics, and to Faculties of Medicine in chemistry and biology.

Table 4. First-Year Full-time Undergraduates (First-degree Courses) (UK)
(UGC 1969; HESA 2005)

Subjects	1966/1967	2003/2004
Medicine (pre-clinical)	2,830	6,115
Pharmacy	542	2,735
Biochemistry	297	1,955
Chemistry	2,552	3,315
Materials science	-	70
Physics	2,001	2,840
Geology	212	1,470
Environmental science[1]	3	2,160
Forensic science[2]	-	685
Mathematics	2,688	5,480
Chemical Engineering	807	700
Engineering (other)	8,476	23,860
Computer Science	-	16,815

Notes. [1,2] Discrete figures for environmental and forensic science are not reported for 2003/2004. Numbers are estimated from figures for earlier years.

From the numbers in Tables 2 and 4 it is evident that all these demands cannot be satisfied. It follows that candidates with A-level grades lower than grade C will have been admitted. This is not a new development but the implications of the lower abilities and initial attainments associated with grades D and E are of growing concern especially in the less prestigious universities.

The sciences and engineering have also changed over the past half century. Whereas in the past chemistry and physics could have been taught and practised as "small" sciences, this is no longer true. Their subject matter is more extensive and diverse; not merely is there more to be learned, the range of specialisms, techniques and expertise is greatly enlarged. They are also bigger in costs: the capital costs of equipment and facilities; the operating costs of consumables and staffing. No longer can chemistry or the other physical sciences and engineering be accommodated in small departments.

When the arguments about student numbers and costs are combined they generate a powerful logic (**Figure 1**). If, for example, the current total number of chemistry students were to be distributed over all the (approximately) 100 universities, this would give an average total enrolment of 130 students.[6] With a target student/staff ratio of 15 this would correspond to a total academic staff of 9. Such a department would be properly perceived to be too small either to cover a professionally adequate syllabus or to justify the necessary capital costs. Moreover, a non-prestigious university could attract even this average number only by enrolling students with less than good A-level grades. Its teaching burden would be increased and several of its important "performance indicators" would be weakened. Further, by application of the "Matthew Principle", it would be unlikely to be able to attract or retain even an average number of graduate students or to obtain significant research funding. Inevitably the university would see advantage in redirecting its block-grant resources to areas of high student demand and potential growth. An alternative scenario (Figure 1) of concentrating students in a much smaller number of departments gives figures that offer

Figure 1. Undergraduate Teaching Load and Academic Staff Numbers

Chemistry

Total Student Load (as ug): 13,200

Student/Staff ratio[1]: 15/1 **Funded Academic Staff 880**

Number of Departments (assumed)

(a) 100 **(b) 30**

Average Number of Academic Staff

(a) 9 **(b) 30**

(Note. [1] Existing s/s ratio. Assumes weightings p-t students 0.5, pg students 2) (HESA 2005) a more persuasive basis academically, financially and managerially. It appears that the internal market within universities is adopting this course, not just for chemistry but for physics and engineering. In the past 10 years some 28 chemistry and a similar number of physics departments have closed; and in engineering, closures have been accompanied by mergers of electrical, mechanical and civil engineering departments into general engineering departments.

First-degree courses.

Establishment of mass higher education has required significant modifications to university courses – indeed this might be construed as a criterion of massification. With the aim of accommodating "non-traditional" students and attitudes, a variety of new, shorter sub-degree courses, and new formulations and new prescriptions for degree courses have become available. In public debates in Europe, these changes are regularly presented as timely changes to an increasingly irrelevant, rigid and outdated structure or, alternatively, as evidence of degraded university standards, and dumbing-down of courses to justify targets for expansion. Probably both views contain elements of truth.

In these circumstances, a decision to implement longer and more rigorous first-degree courses might appear to be foolish. Yet this is precisely what has happened over the past 15 years in engineering, mathematics, physics and chemistry. It is not though entirely perverse. In these subject areas there is little or no evidence that actual or potential students have non-traditional attitudes or aspirations. The physical science and engineering departments offer few sub-degree courses; and the emergence and growth of new subject specialisms is reflected in creation of new degree courses (Table 4) rather than by extension of existing courses. So the driving force for change has focussed on the need to sustain the relevance and effectiveness of the traditional courses. Three aspects of this driving force can be identified.

(a) Limitations imposed by the scope and standards of the GCE A-level syllabus and teaching resources in secondary schools means an increasing proportion of students requires

Table 5. First-year Full-time Undergraduates (First-degree Courses) (GB) Expected Length of Course (UGC, 1984; HESA, 2005)

Note. Figures for 4-year courses 1983/1984 indicate numbers of students following "sandwich" courses, which provide the equivalent of one year's industrial experience during the undergraduate course. For 2003/2004 the numbers of 4-year course students include both enhanced first-degree and sandwich course students; sandwich course students are listed separately in the final column of Table 5.

	1983/1984		2003/2004		
Subject	**3-year course**	**4-year course**	**3-year course**	**4-year course**	**Sandwich courses**
Pharmacy	524	147	613	2,049	232
Biochemistry	865	196	1,348	554	268
Chemistry	2,006	415	1,245	1,992	428
Physics	2,393	299	913	1,860	95
Mathematics	4,043	633	3,200	2,187	267
Chemical Engineering	374	442	141	540	122
Engineering (all)	6,994	3,970	8,827	11,473	3,774

longer introductory courses.

(b) Scientific developments have increased not only the extent of knowledge but also the range of relevant knowledge. To meet professional standards this implies that time is needed to accommodate the greater diversity of material.

(c) Both academic departments and the scientific professions emphasise a greater significance for research capabilities. In UK universities this is partly a reflection of the financial benefits flowing from the research assessment exercises; in the UK scientific and engineering industries it reflects the decline of requirements for bulk manufacturing and the demand for new products, processes and technology.

The possibility of modifying undergraduate courses in response to the evident constraints and limitations imposed by the changing environment of secondary education was not adopted. A complementary development, of strengthening and expanding provision of postgraduate masters courses in order to achieve the necessary professional criteria would have conformed to widespread international practice (OECD, 1987). This was indeed proposed by government but supported by neither the professional bodies nor industry and rejected by the universities. The response has been to introduce a 4-year first-degree course that carries a misleading title of MSci or MEng (or sometimes MPhys or MChem) – not to be confused with the postgraduate masters degree of MSc. The new courses run in parallel with the existing 3-year courses, commonly sharing the first and second years. The third year of the new courses allows more advanced material to be included and combined with in-depth study of selected options. A research project occupies a substantial part of the time in the fourth year.

These new "enhanced first-degree" courses attract an increasing proportion of students (**Table 5**). By 2003 over half of all chemistry students were enrolled in MChem courses. For those students with firm professional ambitions this is clearly a prudent decision. The Royal Society of Chemistry indicates that that an MChem degree will eventually become a necessary precursor for registration as a Chartered chemist (CChem). It was initially proposed that completion of an enhanced first degree should be a requirement for enrolment for a PhD (students with a conventional 3-year BSc would require a postgraduate MSc). In the event this has not occurred.

Two universities, Oxford and Cambridge, offer only the enhanced 4-year course. At Oxford in chemistry this is simply a relabelling of the 4-year degree that was established uniquely there more than 50 years ago. Conversely, a substantial minority, one-third of the universities still offering degree courses in chemistry, have not introduced the 4-year enhanced degrees. In this group are universities with small departments of chemistry where neither the resources nor numbers of students are sufficient to allow parallel courses. It appears likely that those departments unable to sustain the enhanced courses will find it increasingly difficult to survive. It must be expected that chemistry, physics and engineering courses will continue the process of concentration in larger departments in the more prestigious universities, and closures in the others.

Conclusions.

Media reports of a crisis in science education emanate from the Royal Society and many of the professional scientific societies. Yet a cross-sectional view of the current academic and professional situation of the physical sciences and engineering would have to be that they are healthy and strong. The universities, despite their perennial problems of funding, are attracting fairly steady numbers of students and their graduates are attractive to employers. The graduates earn salaries and have career opportunities that are substantially better than those available in other disciplines[7] (RSC 2005). Concentration of these professional subjects in larger departments is proving effective in ensuring high academic standards across the full ranges of the enlarged disciplines. Research is maintaining high international standards and in the universities provides world-leadership in identifiable areas. Research in industry contributes a steady stream of innovative products to a highly productive and profitable sector (CIA, 2005). On the basis of such evidence, there was perceived to be no need to identify chemistry, physics and mathematics as "strategic subjects in crisis" requiring institutional funding (HEFCE, 2005).

However, when viewed over an extended time-frame some potential problems do become apparent.

(a) In universities, student demand for degree course in these disciplines will fall. Of the 170,000 teachers of science and mathematics in the non-private schools in England, 43% (73,000) will retire over the next 10 years (DfES, 2000). Replacing them would require recruitment of about 10% of all science and mathematics graduates, far in excess of current recruitment and to jobs that offer less attractive pay and conditions than those available elsewhere in industry and commerce.

(b) Substantial increases in tuition fees in the universities may well discourage even motivated students from enrolling in the enhanced 4-year courses, particularly if universities exercise the opportunity to charge higher fees for more expensive courses.

(c) Increased competition from graduate schools elsewhere in Europe, Australia, China and the USA, and increased charges for tuition and visas in the UK will limit the numbers of overseas research students, currently about one-third of the total.

(d) Decreased demand for science and engineering graduates might result from the trend to move both commercial manufacturing and research overseas to locations of lower costs and higher profits.

While in the event it is unlikely that these effects, individually or collectively, will prove disastrous, they are useful reminders of significant risks implicit in the current structures.

Replacing this introspective view of the situation for physical science and engineering with one offering a wider perspective presents an opportunity to examine a number of significant issues of more general interest. In particular it presents an alternative aspect from which to analyse the consequences of implementation of mass higher education. This novel perspective replaces the dominant characteristics of massification – explosion of numbers, non-traditional students, part-time study and sub-degree level courses – by exposing its effects on the non-growth traditional areas. What have been the consequences for the former elite system of higher education? In quantity the products of elite higher education still constitute a significant proportion of university activity: a wide range of the traditional professions still requires traditional graduates. The process identified by Martin Trow for the research universities in the USA operates also in the UK (Trow 1984). A virtuous cycle of high prestige and ability, attracting funding, academic staff and students, operates selectively to sustain academic excellence and research achievement. In the UK this is evident in Oxford and Cambridge and in the most distinguished colleges of London University. These remain institutions still recognizably structured as traditional, elite universities. The explicit evidence from chemistry, physics, mathematics and engineering, which may be replicated for other professional disciplines and perhaps other traditional subjects, is that research universities elsewhere in the UK also retain their traditional characteristics. Conversely, in the UK's numerically flourishing non-research new universities ("comprehensive" in the Carnegie categorization) the physical sciences and engineering are in the process of vanishing. The implication is that while the UK higher education system has become massified it is far from homogeneous: individual institutions are increasingly differentiated across a spectrum ranging from largely unchanged, elite universities to fully massified, non-traditional institutions.

Burton Clark identified the structure of the UK university system as a pyramid (Clark, 1983). With many institutions and more academic staff aspiring to a place at the apex, the academic programmes and activities in many universities seek to replicate those of the few that are there. The alternative is stigmatized as second class. In the USA, the pyramid is flatter, and is also identifiably stratified. In an institutionally competitive environment, aspiration is focussed on becoming "best among equals" (Clark 2005). There has been a failure in the UK to accept institutional differentiation and the opportunity for achievement and excellence that this confers. In large part this implies inadequate appreciation of the functions required across a system of mass higher education.

The role of higher education is now far more than that of educating well-prepared students for honours degrees and conducting research. In the UK, higher education is needed to remedy the limitations of the secondary education system. In doing so it is simultaneously expensive and inefficient but it is also an effective and a practical solution. To a large extent higher education now provides a means of completing general education at sub-degree level though at some cost to providing the basis of higher education at degree level. It should also be filling the need for a scientifically literate workforce. A persistent belief that the sole function of science in higher education is to educate specialist professional scientists impedes achievement of this objective. The demand for professional scientists and engineers is real and must be met; but it is useful to note that most science graduates are valued, not primarily for their specialist knowledge but for their generic skills in analysing data, extracting and synthesising knowledge, and preparing conclusions. There is a greater intellectual and educational challenge of developing both a product and a market for science-based mass higher education.[8]

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Remarks

1. This implies that students will have studied all 3 subjects to an appropriate standard at school.

2. Historically, the schools' examinations, School Certificate and Higher School Certificate, which preceded the current the General Certificate of Education, Ordinary level and Advanced level, were organised by the universities and constituted "matriculation", i.e. a qualification for entry to university.

3. Requirement of full-time study implied that students would not take part-time jobs. Provision of means-tested maintenance grants to students was accordingly justified on social and educational grounds. It was also valid on economic grounds through facilitating completion of courses within 3 years. Grants were replaced by loans and finally withdrawn in the 1980's.

4. Only 40% of mathematics teachers in non-private secondary schools have degrees in mathematics; for the sciences the figures are biology, 63%; chemistry, 75%; physics, 62% (DfES, 2000).

5. Curiously, in recent years, the number of girls entering the GCE A-level examination in chemistry equals the number of boys; and they are more successful. The proportions of girls entering A-level examinations in other subjects are: mathematics, 40%; physics, 24%; biology, 63%; all subjects, 54% (DfES 2003) (Education and training statistics for the United Kingdom 2003 edition, London HMSO)

6. For simplicity it is assumed that the teaching "load" in chemistry for students from other departments balances the load transferred to other departments by chemistry students taking courses elsewhere. Historically, chemistry, physics and mathematics departments were net importers of teaching load. In recent years, new subject areas have increasingly undertaken responsibility for teaching their own basic science and mathematics.

7. Private rates of return for UK graduates are: law,

17.2%; management, 16.9%; engineering, 15.5%; chemistry, 15.0%; physics, 14.9%; social sciences, 13.5%; medicine, 11.6%; biological sciences,10.2%; history, 8.0%.

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