# TEACHING SCIENCE AND MATHS

- *Is a shortage of qualified teachers looming?*
- *Current and future issues of quality.*

POST TECHNICAL REPORT 88 December 1996

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A majority of teachers in 'shortage' subjects such as physics, chemistry and maths are over 40 and many will retire over the next few years. At the same time, places on many teacher training courses for these subjects remain unfilled. With the emphasis on raising standards at both primary and secondary level, there are concerns that this is being compromised by unavailability of specialist teachers, and that the problem may worsen.

***This note looks at supply and demand for school science and maths teachers and the implications.***

## 1 CURRENT TEACHER SPECIALISMS

In **primary** schools, there are some 160,000 full-time teachers in England, but limited data on their subject qualifications. When the Commons Education Committee reviewed science and technology in schools in 1995, the most recent information was from a DES survey in 1987 when only 22,000 were found to have some (post-A-level) science qualification (of whom 65% were then over 40). Data were unavailable on specific subjects, but the Committee anticipated that biology qualifications would be much more common than physical sciences.

In **secondary schools**, a Royal Society (RS) -sponsored study estimated that there were 33,000 science teachers in maintained secondary schools in England and Wales (E&W) in 1990, while a DfE survey in 1992 surveyed 10% of the 210,000 secondary teachers in England, and found the numbers with a post A-level qualification in scientific subjects in **Table 1 (**English and history are given for comparison). With single sciences, the qualification concerned was a degree in 29-47% of cases; in 19-32% of cases the only science subject qualification beyond A-levels was as a subsidiary subject during training.

**Table 1 POST-A-LEVEL QUALIFICATIONS OF FULL-TIME SECONDARY TEACHERS**

| Subject | Any qualification | % with subject degree | PGCE | BEd, other | Subsidiary level only |
|---|---|---|---|---|---|
| Chemistry | 15,000 | 47 | 12 | 19 | 22 |
| Biology | 15,000 | 29 | 19 | 33 | 19 |
| Physics | 15,800 | 37 | 13 | 24 | 26 |
| Gen. Science | 16,500 | 13 | 32 | 23 | 32 |
| Maths | 38,100 | 29 | 12 | 30 | 29 |
| English | 40,100 | 33 | 9 | 32 | 24 |
| History | 28.800 | 37 | 10 | 29 | 24 |

**Table 2 AGE OF SECONDARY TEACHERS IN ENGLAND**

| | DfE Survey (1992) | | OFSTED (1996) | |
|---|---|---|---|---|
| | 40-49 | 50+ | 40-49 | 50+ |
| Chemistry | 48 | 17 | (all science) | |
| Physics | 46 | 19 | 42.8 | 18.4 |
| Biology | 41 | 14 | | |
| General Science | 34 | 15 | | |
| Maths | 41 | 20 | 44.5 | 19.7 |
| English | 41 | 18 | 42.2 | 17.3 |
| History | 41 | 19 | | |

Much attention has been drawn to the age profile of the teaching profession[1] - as shown in **Table 2**, 49-65% of secondary school teachers in England were over 40 in 1992, and in some subjects (e.g. maths) 20% were over 50 and already eligible for early retirement. This distribution has come about because of the recruitment boom of the late 1960s / early 1970s (when 50,000 teachers were being trained each year) and affects all subjects. However, chemistry, physics and maths appear most affected with more than 60% of teachers over 40. More recent figures from OFSTED (also in Table 2) show that when only **teaching** staff are considered (i.e. excluding those in non-teaching positions), it is **maths teachers** who stand out as older than their counterparts in other subjects. Sciences as a whole have a typical age distribution, but the relative youth of general science and biology teachers means that disproportionately high numbers of **physics and chemistry teachers** will be leaving the profession over the next 5-10 years. In Scotland, similar concerns apply; 61% of secondary maths teachers are over 40 (21% over 50); in science the figures are 67.4% and 20.5% respectively.

In Scotland, teachers cannot usually teach a subject without an advanced subject qualification, but the situation in E&W is somewhat more fluid. **Figure 1** (based on the 1992 DfE survey in secondary schools) shows

**1. E.g. the Association of Science Education (ASE), the British Association and the Royal Society's "Only a Teacher" in 1991, OFSTED's review of Science and Mathematics in Schools in 1994, and the Education Committee's Inquiry into Science and Technology Education in 1995.**

that pupils are more likely to be taught by a teacher with a degree in the subject concerned at ages 16-18, than at earlier ages. Thus at age 11-13, only 42% of physics classes in England are taught by a teacher with a degree in physics, but this rises to 67% at age 16-18. This means that **a majority of younger age groups are taught biology, maths and physics by teachers without that subject degree**, and up to 28% of science and maths teachers of 11-13 year-olds have **no (post A-level) qualification in these subjects at all** (comparable figures for English and history are 19-22%). One notable feature is the low proportion of general science lessons taught by general science graduates. This will be due to many such lessons being taken by single science graduates, although the 1992 survey does not allow this to be quantified.

The Royal Society and others thus point out that even though schools are able to place teachers in front of classes, there are real shortages of **appropriately qualified** teachers. Other statistics illustrating this point are:

- in 1990, 23.8% of secondary teachers taught physics, but only 18.8% had a physics main qualification.
- 39.3% of 'science' teachers for under-16s had biology, 18.8% chemistry and only 10.8% physics qualifications.
- In 1990, the (then) DES predicted that by 1995 there would be a shortfall of 2,000 chemistry teachers and 1,500 physics teachers (out of a target of 11,000 of each). These estimates have not been updated.

In Scotland, 11.2% of secondary teachers had a *"secondary qualification in maths"* and 22.4% one in a science. At first sight, this suggests that there are fewer science and maths qualifications among Scottish teachers, but this may reflect different definitions of qualification. The Scottish minimum requirement is for *"2 graduating passes"* - relevant parts of degree courses (from 2000 this will rise to 3 graduating passes). Most of the Scottish qualifications will thus involve a degree in the subject concerned. In contrast, the DfE survey in Table 1 included all qualifications after A-level, and those with a subject degree or PGCE were in the minority (e.g. 8.9% of teachers have a maths degree compared with the 21% classed by DfE as *"qualified "* in maths).

## 2 SCIENCE AND MATHS EDUCATION

A 'benchmark' of England and Scotlands' performance in comparison with schools in a number of other countries was released by OFSTED earlier in 1996. This shows (**Table 3**) that in maths, UK pupils' achievements up to age 15 are in the lower half of international comparisons, even though at pre-university specialist level, UK standards remain high for the relatively small numbers of students involved. On science, relative performance at up to age 15 is slightly better, with standards about the international average.

**Figure 1 PERIODS TAUGHT BY TEACHERS WITH A DEGREE IN THAT SUBJECT**

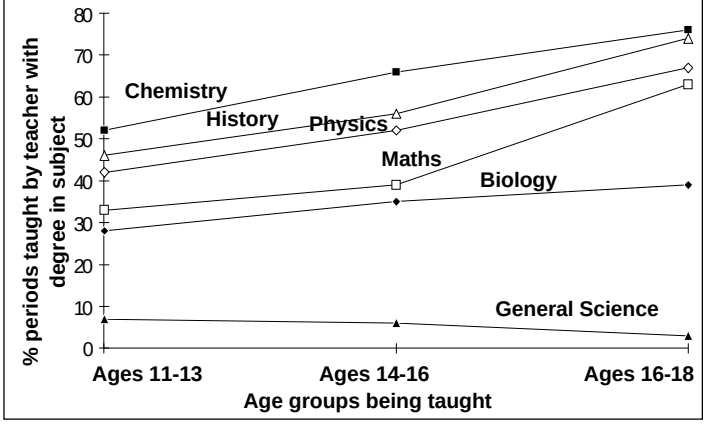



**Table 3 INTERNATIONAL COMPARISONS**

| Study Title | Year | Rank (up to age 15) | Rank (pre-university) |
|---|---|---|---|
| *Mathematics* | | | |
| IEA FIMS* | 1964 | 6/12 | 2/12 (7/12 non-specialists) |
| IEA SIMS | 1982/3 | 11/20 | 3/15 |
| IAEP 1 | 1988 | 9/12 | |
| IAEP 2 | 1990 | 12/21 | |
| *Sciences* | | | |
| IEA FISS | 1970/2 | 9/14 | 5/14 |
| IEA SISS | 1983/5 | 17/19 | B3/16; C2/16; P2/16 |
| IAEPS | 1988 | P3/12; C,B 6/12 | |
| IAEPS 2 | 1990 | 9/19 | |

** See OFSTED Review "A World Apart" for definitions P=physics etc.*

**Table 4 MEDIAN SCORES IN TEN COUNTRIES (13-year-olds)**

| | MATHS | | SCIENCES | |
|---|---|---|---|---|
| COUNTRY | median score | rank | median score | rank |
| Canada | 498 | 5 | 511 | 5 |
| England | 482 | 9 | 529 | 3 |
| France | 498 | 5 | 455 | 10 |
| Hungary | 504 | 4 | 521 | 4 |
| Japan | 572 | 2 | 535 | 2 |
| Scotland | 486 | 8 | 504 | 8 |
| Singapore | 608 | 1 | 555 | 1 |
| Sweden | 497 | 7 | 511 | 5 |
| Switzerland | 519 | 3 | 495 | 9 |
| U.S.A. | 472 | 10 | 510 | 7 |

*Source: Third International Mathematics and Science Study.*

The most recent survey has just been released (the Third International Mathematics and Science Study (TIMSS)) and looked at performance across over 40 countries at age 13 in tests carried out in 1995. English and Scottish pupils performed relatively poorly in maths - of the 25 countries where tests were broadly comparable, English pupils came sixteenth (a fall in position from the last survey in 1990 when England was twelfth out of 21). When compared against 10 industrialised countries representing the main areas of Europe (West and East), North America and the Far East (**Table 4**), performance in England and Scotland was only just ahead of the lowest perfomer (the USA). Possible contributory factors to the decline in relative standards include time pressures (the time on maths has fallen by 20 minutes per week since the last survey), and teaching style with a move away from knowledge and rigour in favour of practical tasks.

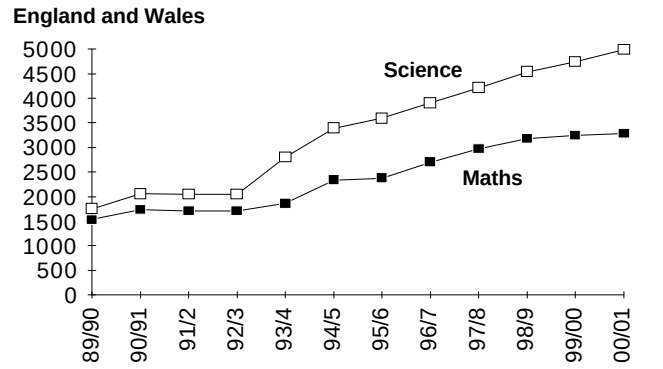
The picture was much better with science with England and Scotland in third and fourth positions relative to the 10 countries in Table 4. In the wider survey, England came sixth out of the 25 countries with comparable tests. Analysts attribute the improved performance (at least in part) to an increase in the amount of time spent on science in schools. Science tuition has undergone substantial revision in recent years in E&W - particularly at primary school where the National Curriculum introduced structured science tuition for the first time. This was accompanied by training programmes for teachers and science 'coordinators'[2], the result of which is that OFSTED regards science at primary level as a success. However the latest results underline concern over weaknesses in maths, and poor understanding and ability in maths undermines scientific subjects-especially physics, chemistry and (later) engineering.

Teacher knowledge and the quality of science and technology education in England were examined in the Education Committee's 1995 report. At **primary level**, there was unanimous agreement that serious problems remained over primary teachers' lack of subject knowledge, making primary schools heavily dependent on science coordinators. At the same time, the committee found that often there was either no suitable coordinator available in science or insufficient time to prepare the necessary support. The Committee concluded that as a result, primary teachers found it difficult to draw out the principles and concepts involved in science.

An increasing number of primary schools now use specialists to teach science at Key Stage (KS)2, instead of the class teacher. This goes some way to overcoming concerns at the time of the Education Committee Inquiry, and may also help reduce the contrast between science teaching styles across the primary / secondary interface which the Committee felt contributed to a "*falling off*" in pupils' enthusiasm after KS2. What many regard as a desirable trend cannot however apply in all cases (e.g. because small schools may lack teachers with specialist knowledge). OFSTED and others thus do not see the delivery of effective education as being wholly **dependent** on increased use of specialists. However, the success with their use does bring into sharper focus the question of whether there are sufficient primary teachers with the required subject qualifications, and the continued need for effective training and use of subject coordinators whatever the approach.

At **secondary level**, Table 1 showed the numbers of teachers qualified in the relevant subjects in England. Of course, a teacher's qualification is only one aspect of his / her effectiveness, but knowledge of the subject matter is clearly a necessary (if not sufficient) precondition of effective education. Indeed, there is a firm requirement in Scotland that classes must be taught by teachers qualified in that subject. As already mentioned, many pre-A-level classes are taught by teachers with no direct qualification in those subjects, and learned societies and others are especially concerned over the effects of inappropriately qualified people teaching science and maths. Concerns are not just over the quality of teaching but over potential weaknesses as role models[3] influencing pupils in their choice of subjects. The Education Committee found that concerns centred particularly on the delivery of physical sciences and the difficulty of single science specialists adapting to the 'balanced' science curriculum at KS3.

**Figure 2 TRAINING TARGETS IN SCIENCE AND MATHS**




## 3 TEACHER TRAINING TRENDS

The Teacher Training Agency (TTA) was established in 1994 to be responsible for raising standards in teacher training. Overall training targets are set by the DfEE using a staffing model devised before the introduction of the National Curriculum and Local Management of Schools (LMS). As such, the DFEE system does not take regional needs into account and is also based on data which are some years out of date. Nevertheless the overall demographic trends of an ageing teaching population and an increase in the next few years in the number of pupils are clear, and lead to a substantial increase in training targets over the next 5 years. As shown in **Figure 2**, targets will increase from 3,590 in 1995 to 5,065 in 2001 for secondary science training (these are not broken down into separate targets for the individual sciences) and from 2,380 to 3,290 for maths.

**Figure 3** shows that secondary courses struggle to fill the available spaces in science and maths (as well in other 'shortage' subjects such as modern foreign languages and RE). The failure to fill existing places is not new - as shown in Figure 3, initial teacher training (ITT) courses have been consistently 20-30% undersubscribed since 1984, with an improvement from 1991 to 1994

**2. Science coordinators in primary school are teachers with a special knowledge of the subject concerned and who can assist class teachers with those lessons. Assistance ranges from just providing an inventory of books and other learning resources to taking the class for that subject.**

**3. Parallel concerns over role models are also emerging over the increasing feminisation of teaching with the percentage of male teachers in primary schools falling from 21.9% in 1985 to 17.8% in 1995; in secondary schools from 54% (1985) to 49% in 1995.**

coinciding with the economy recession. Now that the economy is improving (and with it vacancies in areas other than teaching), it is once again **proving impossible to fill available places**. Overall the deficit is around 18% but physics courses are proving particularly difficult to fill, with **only 488 applicants** (relative to a science total of nearly 3,500). Maths is also seriously underrepresented, and **not more than 50% of the available places appear likely to be filled**. Recruitment to the profession is thus a critical issue and is attracting increased attention from the TTA, which is strengthening its resources in this area with the appointment of a Head of Teacher Supply and specialist adviser.

The E&W position contrasts to a degree with that in Scotland, where specific subject targets are not set in training. However, training institutions are required to allocate 75% of their places to *"priority subjects"* - the current ones are physics, maths, English, foreign languages, technical education, religious education, computing and music. Unlike E&W, there are still more applications than available places in science and mathematics, though the excess demand is decreasing.

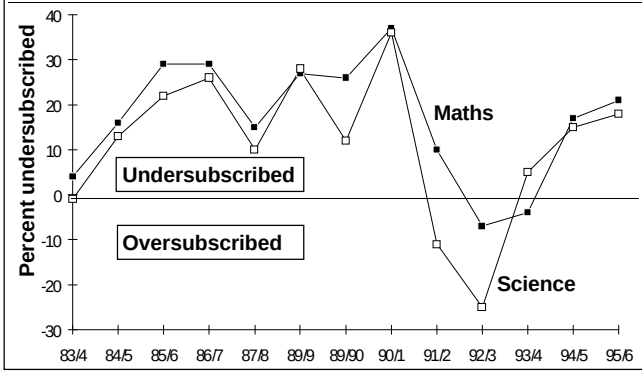
Training institutions are no longer the only route into teaching, and the Government has set up the Licensed Teacher scheme and school-centred training to offer alternative pathways. The LT scheme contributes 1.5% of trainees each year in total in England, while school-centred ITT (SCITT) accounts for around 90 science trainees overall.

In contrast to secondary training, primary courses continue to be heavily oversubscribed, but there are no routine data collected on the subject specialisms (degree level for the 4500 to be recruited via PGCE; A-level for the 7600 BEd places in 1995/6) of the candidates accepted or rejected. This makes it very difficult to know **whether primary schools are able to assemble appropriate skills, despite the trend to more teaching done by specialists**.

## 4 STRUCTURE OF SHORTAGES

Shortages in science and maths teachers have been a consistent feature of the UK school system, with the first official recognition of the problem in the 1875 Devonshire Report. The shortcomings in science and maths education have never been overcome fully, and the intervening years have been punctuated with studies and reports showing once again that problems remain. Thus the Dainton Report of 1968 pointed to the acute shortage of graduate scientists in schools, the 'crisis' in teacher supply led to bursaries in shortage subjects (starting with physics in 1986), and more recent analyses described in this note bring us to the present day. Basically, many observers see an endemic series of positive 'feedbacks' **leading to a 'vicious spiral' where not enough science graduates go into teaching, the teaching of science suffers relative to other subjects, not enough pupils choose sciences, so that there are insufficient science graduates who choose to go into teaching etc.**

**Figure 3 UNFILLED PLACES ON ITT COURSES**




This 'spiral' has not been short of analysis or of proposals to try and break it. Governments have tried bursaries, targets, and other measures to try and increase the supply of qualified teachers. The importance of increasing the scientific and mathematical literacy of the population has also been recognised in the form of the National Curriculum and other means of encouraging more students to take sciences and maths at A and degree level. Nevertheless concerns remain that, after a short moderation in the scale of shortages of new teachers, the acute shortages of the 1980s look likely to return; moreover that many of the concerns over the quality of science and maths tuition are still being overlooked.

Putting a figure on 'shortages' is however made difficult by the lack of regular statistics, and attempts to bring these issues into focus have had to rely on bodies such as the RS commissioning academic experts to bring together many separate sources of statistics. Those working in the field see greater scope for the DfEE (and now the TTA) to design its statistical surveys **to allow performance towards key policy objectives to be continuously monitored**. For instance, DfEE could collect more data on subject specialisms for both primary and secondary level so that the position on specific skills (whether science, music or modern languages) can be continuously monitored and early adjustments made to training and related targets. Some data however can only be collected from schools or higher education Institutions (HEI), and here there is a need to balance requirements against the demands made on their time.

As already mentioned, concern in England is mainly over a shortfall in the numbers of teachers qualified in physical sciences and maths (typified by DES' 1990 estimate of a 15-20% shortfall of physics and chemistry teachers by 1995). In Scotland, physics and maths are priority subjects. Despite this, vacancy rates remain

**Table 5** MEDIAN SALARIES IN 1996 FOR RSC FELLOWS AND MEMBERS

| Age | School teaching | All Professions | % behind |
|---|---|---|---|
| 25-29 | 16,900 | 20,200 | 16.3 |
| 35-39 | 23,000 | 28,500 | 19.3 |
| 55-59 | 27,700 | 34,500 | 19.7 |

**Table 6** RECENT DfEE/TTA INITIATIVES SUPPORTING SCIENCE AND MATHS TEACHING

- ▲ Shortage subject Bursary (SSB).
- ▲ Priority Subject Recruitment Scheme (PSRS).
- ▲ Support for Returners (via Sheffield Hallam University).
- ▲ Primary ITT Criteria (Circular 14/93).
- ▲ Promotional work byTeaching as a Career Unit (TASC) and TTA Taster Courses.
- ▲ Directed GEST funding for 1996-7 is £16.7M to enhance primary teacher's subject knowledge, with focus on science and maths.
- ▲ Open University PGCE course support for *inter alia* science and maths.

low for science and maths as for other subjects (0.2% in 1995). How can such conflicting indicators be resolved? Factors which may hide shortages include:

- 'balanced' science tuition makes it easier to regard any science background as suitable - e.g. a teacher trained in biology taking 'science' appears less of a mismatch than when teaching the same material under the label of physics or chemistry.
- With LMS and competition between schools, some may be reluctant to record vacancies in key subjects because of the effect this may have on pupil / parent perceptions of the quality of teaching at that school.
- Difficulties of recruitment may lead some heads to 'make do' with other staff or stop offering the (e.g. physics) course.
- Class size may drift up to mask a shortage.

The existence of a real shortage is supported by a recent TES survey which revealed that 50% or more of the heads responding were experiencing problems of recruitment or retention of maths and science teachers.

The low vacancy rate however illustrates that resolving current difficulties is not just a question of supply. Were 2,000 qualified physics teachers to appear overnight, it would not be possible to employ them because most of the teaching positions are already occupied. Indeed, some PGCE graduates already encounter difficulties in obtaining employment, perhaps because a high proportion of science and maths PGCE trainees are mature and may either appear too expensive to some heads and / or have difficulty in moving to where the vacancies are located.

As many observers have pointed out in the past, the persistence of supply problems is a reflection of (*inter alia*):

- the number of physics, chemistry and mathematics graduates from which to draw trainees is limited;
- teaching is rarely the first career choice, so training applications are related to the state of the economy;
- now that many finish their degree course with significant student loan repayment obligations, teaching suffers from the added disadvantage of another year's training to add to debt;
- the differential between salaries for science and maths graduates between teaching and other professions can be substantial (e.g. the median salary for Fellows and Members of the Royal Society of Chemistry in Teaching is compared with the average of all employment in **Table 5**)
- many science and maths trainees are mature (45% over 26), and may not be favoured by some heads because they are more expensive or may not all have the right personal skills;
- the relatively high 'wastage' rate (28.5% of physics PGCE entrants in 1985-89 failed to complete training or to get a teaching job);
- a low proportion of women in physics, chemistry and maths (women tend to be more positive to teaching than men);
- some surveys also suggest that the primary attraction of physical science (to search after the order and pattern of nature) does not mesh well with perceptions of the modern classroom!

While none of these factors is in itself new, combined with the increasing rate at which teachers will be leaving the profession, a rising school roll, and little prospect of meeting training targets without radical revision of pay and career structures, **current 'hidden' shortfalls can be expected to turn into the overt shortages seen in the 1980s**.

## 5 INCREASING THE SUPPLY

There have been a number of initiatives in recent years (see **Table 6**). For instance, in the late 1980s, the DES launched the Teaching as a Career (TASC) initiative which provided objective advice at both national and regional level to try and generate more interest among graduates of teaching as a career. TASC was disbanded in 1994. The TTA has since commissioned consultants Hill and Knowlton to seek to generate interest among graduates and others in teaching. Despite this, science and maths places remain unfilled and there is concern whether the current service provided can match the national and regional coverage of the earlier TASC.

The difficulty of attracting more trainees from **the fresh graduate pool** is compounded by the numbers of science A-levels, and of graduate scientists and mathematicians not having increased in line with other subjects in recent years (**Figures 4 and 5** on page 6)). This is despite success in increasing the numbers taking science at GCSE level. Moreover, within A-level programmes, there has been a shift to combined A-levels (where science is taken with economics or arts subjects) away from science / maths combinations, which have

fallen from 27.6% of A-level entries in 1984 to 17% this year. As OFSTED points out, it is the latter that tend to form the main route for science or engineering degrees, and the prospects of a surge in the numbers of science or maths graduates over the next few years thus appear remote.

The question of teacher supply thus meshes with wider questions on the total supply of students doing science or maths. Here, some see the output of science, maths, engineering etc. graduates merely in terms of whether they meet the specialist demands of industry and academia. Others contrast this with the arts and humanities, where the suitability of these subjects for general educational purposes is not questioned, and numbers of (e.g. history) degrees are not linked to the demands for specialists. They argue that judging the adequacy of supply purely on measuring specialist demands in industry, commerce and government misses the fundamental point that **a science or maths education is an appropriate and increasingly important foundation** for playing a full role in a society so dependent on technology.

The failure to transform the increased numbers taking science at GCSE into significantly increased numbers at A-level and at degree level is a source of disappointment to OFSTED, learned societies and many others (including government). While not the primary focus of this note, contributory factors may include the general perceptions of science and its career prospects among pupils weighed against **the relative difficulty of the courses**[4]. In view of the emphasis in university admission on A-level grades, this creates an incentive to students to opt for the 'easier' subjects. Ways of remedying this bias are under review by Sir Ron Dearing.

It has to be said however that the UK is not alone in encountering difficulty in increasing the numbers attracted to science, and compares favourably with a number of other countries in the proportion of its population with scientific qualifications (see POSTnote 69). Moreover, even in subjects where there is a relatively buoyant supply of graduates, teaching remains low on the priority of most seeking jobs. Graduates entering secondary teacher training also tend to have a poorer class degree in science than in other subjects - thus in maths and physical sciences in 1986-91, 35% had a third class or lower degree, compared with only 5% of English and history entrants. There is concern that this may translate to a less confident, exciting and inspirational role model for pupils in the sciences with consequences for pupil choices at A-level.

**4. A review in 1994 by the University on Tyne, found that maths and science were the most difficult subjects in which to achieve a given grade. The 'easiest' subjects (art, communications studies and theatre studies) awarded their pupils A-levels a full two grades higher than science/maths for the same level of difficulty. That is, an A in art is equivalent to a C in science. Other subjects lie between these two extremes.**

**Figure 4 SECOND YEAR SIXTH FORMERS ON A-LEVEL COURSES**

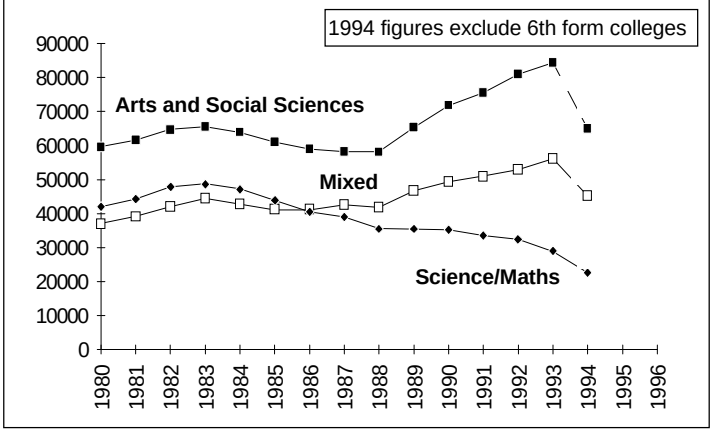
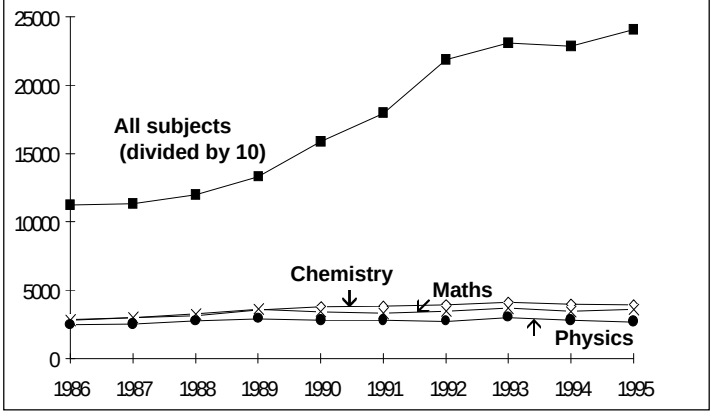



**Figure 5 ACCEPTANCES TO DEGREE COURSES**




One area where numbers are on the increase is in students taking one or two science A-levels as part of combined A-levels (or GNVQs with a science component). There are parallel trends in degrees towards combined and joint honours where science forms 30-70% of the content This group is a possible source of science / maths teachers, but **graduates may not qualify for science PGCE courses and even if admitted may find that the subject content is insufficient**. This may require training courses to be tailored to such entrants, with **greater emphasis on the subject content of ITT**. Such courses could also serve to increase the number of 'conversion' courses for existing teachers to enable them to build up their knowledge base in shortage subjects (e.g. to assist a biology graduate to teach chemistry or physics). Such training would be **best performed by university science departments** rather than education departments alone.

**Mature trainees** from industry, academia, the Services and other sources of technically qualified staff, form another important route into PGCE courses (up to half the entrants into science PGCE courses are over 26). This supply is very susceptible to fluctuations in the overall condition of the economy, as alternative employment opportunities and labour shakeouts vary. The last year has seen a particularly sharp fall in the number of mature entrants to science and maths ITT - e.g. **maths applications at the beginning of 1996 from over-30s were only 24% of their 1995 level.**

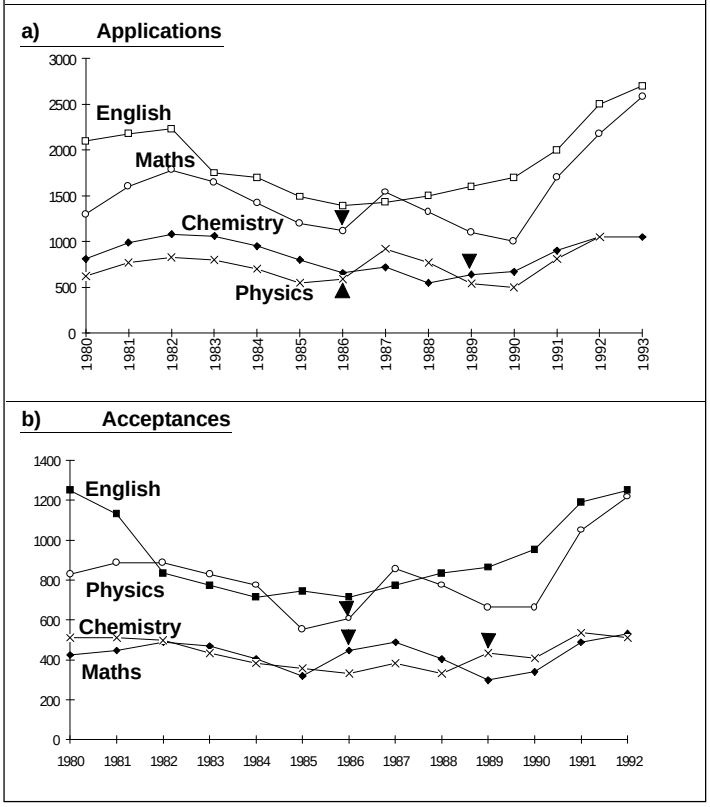
In this context, some (e.g. the Association of University and College Lecturers) see the state of recruitment for secondary school science and maths as so serious that special measures should be put in place, with a particular priority to tap into sources of knowledgeable manpower released from HM forces and industrial restructuring. They argue that means **must be found to allow mature men and women to train and gain experience in teaching with the minimum delay and cost** - particularly since some current trends are working against the mature entrant. General pressures on training costs are transferring some costs to students, while changes in grant regulations reduce support for dependents, living away from home etc. Another factor is the declining role of LEAs in school recruitment, and the loss of funds to assist, for instance in helping a mature graduate move to a school with a vacancy.

The TTA has already set up the 'Target teaching' scheme, aimed at members of the Forces, which will encourage and assist their entry into teaching. Both DfEE and TTA are also looking at wider employment routes into teaching to see what barriers can be overcome. Measures could include:-

- Giving fuller recognition to existing qualifications and experience in attaining qualified teacher status. For example, some MoD grades have found themselves unable to train as teachers because, despite their technical training and knowledge, they do not possess a degree. One way of resolving this would be for relevant MoD training to be accredited to a university so that it counts towards a degree.
- Grants and bursaries during training (these could be linked to teaching for a minimum period).
- Greater sensitivity to regional dimensions. Here, the TTA is looking at better meshing of the regional nature of supply and demand, by taking account of geographical issues when allocating student target numbers to institutions, and encouraging schools to consider longer term recruitment strategies.
- Helping reduce the drop-out rate for mature entrants by allowing students to find out whether they are suited to teaching; e.g. via 'taster' courses.
- The DfEE and the TTA are developing the employment-based 'graduate teacher' route. The Target Teaching scheme is also offers a distance learning package which can prepare for entry to teaching through the Licensed Teacher scheme.

In the past, there have been many **re-entrants,** particularly into primary schools. However, the barriers in the way of returners have grown with the introduction of new ways of working (e.g. the National Curriculum and assessment), and **new measures may be needed to allow inactive teachers to stay in touch with teaching** (e.g. via occasional classroom visits and experience), to encourage (if appropriate a phased) return and provide the necessary refresher courses and INSET courses. The TTA has already funded some courses for returners and is considering future support in this area.

**Figure 6 EFFECTS OF BURSARIES ON PGCE NUMBERS**




**Postgraduate researchers** have not traditionally looked to teaching at the end of their PhD course, but one initiative is relevant here, launched by two Research Councils (EPSRC and PPARC) via Sheffield Hallam University. This **Pupil Researcher Initiative** involves pupils at KS4 in their own research and provides some 500 PhD students to act as role models and assist in investigative work. One side-effect has been that some PhD students have decided to pursue a teaching career.

One tool to increase the supply of specialists teachers has been the training **bursary -** starting with physics in 1986, extended to chemistry in 1989 and then to biology and languages. **Figure 6** shows the effects in maths, physics and chemistry against English (no bursary) and indicates that while numbers may have increased in the short term, impact was short-lived. Indeed because of the limited pool of physical science candidates, the physics bursary is credited with causing some chemistry graduates to register for physics rather than chemistry, thus merely displacing the shortage.

These shortage-subject specific bursaries were seen by Government as inflexible and offering poor value for money, and were replaced by the Priority Subject Recruitment Scheme in 1996, which devolves to training institutions decisions over how best to deploy the funds. Since then, some have continued the old scheme; others have focused on one subject (e.g. physics) and

others used different approaches still. The consistency of the former national scheme has thus been lost, and graduates considering training no longer know the 'going rate' for, say, a physics PGCE. Indeed, it may be possible to 'shop around' for the best bursary, playing one institution off against the other. An additional factor is that because it is fragmented, the task of assessing its effectiveness has become more difficult. There is thus **concern that the new scheme is having less impact than the one it replaced**, and there is much support for a return to a national scheme.

Finally, in the debate over supply a further complications arises from the blurring of the traditional distinctions between physics, chemistry and biology with the introduction of 'balanced' science. Some see this as weakening the need to aim for roughly similar numbers of physicists, biologists and chemists in teaching science, but learned societies point out that these subjects are still taught separately much of the time, and that it is important to maintain as far as possible a proportionate mix of teachers founded in the three main sciences. The importance of the initial degree subject is reinforced by the limited subject content of the 1-year PGCE which cannot be expected to provide the knowledge for a graduate in one science to teach all parts of the science curriculum. On this basis, the DfEE's use of a single 'science' category for training targets has been criticised, and it is seen as important to monitor the subject specialisms of trainees and the mix of biology, chemistry, physics and other degrees. Differentiation between the sciences continues in Scotland: physics is currently designated a priority subject for recruitment, while chemistry and biology remain in adequate supply.

## 6 MAKING THE MOST OF TEACHERS

New supply is, of course, only one side of the coin - the other is whether the education system can retain (whether during training or once teaching) good quality teachers. Historically, resignations by science teachers have been higher than average (e.g. in 1989/90, resignations in sciences were 12.3-16.7% relative to an average of 11.6% in secondary schools). Half of these are resignations in order to move to another school and not a loss to the profession, but they still represent a loss to the school. Reviews[1] suggest contributory factors specific to science teaching include those relevant to initial recruitment (page 5) but in addition:

- dilution of single subject specialist status in favour of science generalist. This increases the amount of 'mis-match' between what is being taught and the knowledge of the teacher, affecting teacher's confidence in their skills and qualifications;
- poor laboratory facilities and equipment, and pressure on staff (technician) support;
- inability to engage in effective training and professional development (see Section 7).

There are other factors operating. In shortage subjects such as physics and maths, candidates are often offered extra increments to attract or retain them, but since different rates of pay for shortage subjects are not applied, such **incentive payments** have to be tied to extra responsibilities (e.g. careers adviser). They thus have the perverse effect of taking time away from teaching the shortage subject and speeding promotion out of the classroom, and may be one reason why proportionately more physical science teachers are found in senior (non-teaching) posts. Many observers have pointed out in the past that this is a consequence of the limited ability to reward shortage skills and progress a career through teaching, and see it as a **paradox that reward systems imply that teaching as such appears not to be the main priority of the education system**.

An additional factor is that retirement will increasingly feature as a main cause of loss in maths and the physical sciences. This raises the question whether it is appropriate to **encourage early retirement** in shortage subjects. On the contrary, there could be a case for allowing **voluntary extension** beyond the usual retirement age for high quality teachers in these subjects.

Mention has also been made of the **regional nature of shortages**, whereby mature entrants may just not be living where the vacancies exist. Thus many industries which have seen significant shake-outs of staff in recent years (e.g. the chemical industry) are concentrated in only a few locations (e.g. Teesside) and training mature teachers may be fruitless if arrangements are not made to help them move to where job vacancies exist. In this context, one of the side effects of LMS devolution has been to reduce the availability of 'welcome' packages operated via the LEA, and schools will generally try to avoid having to pay extra for a new teacher. This reinforces the importance of ensuring that means of overcoming such market inefficiencies (e.g. a central source of mobility support) are provided.

## 7 PRIMARY SPECIALISMS

At primary level, the concept of shortages in specialist subjects is less easy to define in view of the emphasis on class teachers teaching across the curriculum and, as pointed out earlier, data on primary teachers' subject specialisms are limited. The Government recognises the importance of attracting more primary trainee teachers with specific subject qualifications, and a number of measures may help improve the scientific and mathematical literacy of new primary trainees (Section 8).

There is however no information on the current balance of subjects featured in current primary intake, and the overwhelmingly female **intake to primary ITT means that maths and physical sciences and maths are almost certain to be under-represented**. Other factors may exacerbate this intake bias and discriminate against candidates with science and maths A-levels or degrees. For instance, with the contraction in primary training places over the last four years, applications greatly exceed places. Since colleges grant PGCE places on a first-come-first-served basis, people applying later (e.g. after they have looked at other job or educational opportunities) will be disadvantaged. Intuitively, science and maths (and other shortage subjects) are likely to be in this category. In view of the trend to specialist teaching at KS2, it is becoming more important to ensure a balance of skills among primary as well as secondary teachers, and thus some see a need for a policy to try and achieve this. Options would include encouraging institutions to monitor the balance of entrant skills and offering **more science and maths specialisms options in primary ITT**; - in these respects, the TTA is supporting pilot trials in some training institutions to offer specialist modules for KS2 and 3.

At the least, however, **a need is seen for data** on:

- the extent to which candidates with relative strengths in science and maths are favoured (or not) in the selection process;
- the range of qualifications in those accepted;
- the range of qualifications of the typical applicant;

so as to plan further measures if necessary.

Recent DfEE estimates are that, of the new teachers entering primary schools in 1995/6, those with some science training (unspecified) comprised 14% and those with maths 4%, compared with 19% for English and 8% for history. Whether or not this is an adequate balance, there is evidence from OFSTED's New Teachers in Schools Survey that primary schools **do not match school needs in science and maths to the candidates' subject specialisms** despite the obvious attractions of assembling a suitable portfolio of skills. There may thus still be room for a greater awareness among Heads of the need to have staff confident in maths and sciences - such considerations could feature in the new TTA **heads' training initiatives such as HEADLAMP** and the new National Professional Qualification for Headship (NPQH).

OFSTED and the Education Committee both found that **science and maths coordinators** in primary schools often had insufficient preparation time to be effective. As shown in a recent Office of Manpower Economics survey, teachers' workloads have increased in recent years and primary teachers now average a 50.8 hour week placing extra pressures on the time available for support activities.

# 8 QUALITY ISSUES

Concerns expressed over the last 5-10 years over the quality of science and maths education focus on:

- the lack of competition for secondary training places;
- the failure to attract enough of the better graduates;
- poor motivation exacerbated by the poor state of laboratories and equipment, and by perceived loss of status for specialists teaching 'balanced' courses;
- lack of confidence in knowledge, skills and experience from KS2 upwards in maths and science.
- questions over the style of maths teaching - in particular the reduced emphasis on knowledge and practice in favour of using and applying maths in practical tasks.

These factors emerge from several studies[1], but in particular, OFSTED identified maths as the weakest part of the primary curriculum in its 1994 review and physical sciences as especially weak and under-represented at secondary level.

Some measures have been taken at **primary** level - from 1996, a minimum of 150 hours will be spent in primary ITT courses for each of maths, science and English, and from 1998, all new entrants born after 1979 should have a GCSE grade C in science or equivalent. However, there is a **current issue over the redirection of centrally supported training under GEST** away from science to locally determined priorities. Many argue that in view of the special demands made by the science curriculum, provision still needs to be made centrally for primary in-service training for maths and science coordinators until such time as higher qualifications have worked their way into the system.

A parallel trend affecting both primary and secondary schools is the decline in the support available from LEAs. A recent survey commissioned by the Royal Society showed that while overall advisory teacher posts had fallen by 34% between 1992/3 and 1994/5, the decline was much greater in science (46%), technology (45%) and maths (43%). Other trends such as to grant-maintained schools lead to further reductions in central LEA support, and schools are thus much more dependent on their own resources. In Scotland, more schools have remained under Local Authority control, and thus central advisory and support services have been relatively strong. This may change however following the break-up of the larger authorities into smaller authorities which may find it difficult to maintain historical levels of central support.

At **secondary** level, many see the key to quality and motivation as institutionalising a scheme for teacher **professional development**[5]. While relevant to all sub-

**5. This is being pursued in the House of Commons Education and Employment Committee's current inquiry into the professional status, recruitment and training of teachers, in which one aspect is the possible role for a General Teaching Council as already exists in Scotland.**

jects, this is particularly important for science, technology and maths since the pace of change is so rapid in these fields - not only has our understanding of traditional phenomena been transformed in recent years, but some fields (e.g. biotechnology, computer technologies in science; topology and chaos theory in maths) have emerged only in the last 10-20 years. Initial qualifications thus have only limited relevance if not regularly 'topped up' with training, and it may be increasingly difficult to develop confidence in the latest fields where a good foundation was lacking in the first place.

Effective training not only improves quality but also helps raise the professional status of teachers relative to other occupations in which scientists continue to expand and develop their knowledge. In this respect, INSET courses (on which some £600M is spent annually) have been criticised in the past for paying insufficient attention to **science subject knowledge**, and has led to some calling for training to be offered by university **science departments** through refresher / updating courses with other scientists, rather than through education departments. Other ideas include allowing some science teachers to take a 'sabbatical' appointment (analogous to the 'teachers in industry' scheme), or of conducting scientific research in schools or outside. Such an approach would need to recognise that the training required would **need time, effort and funding and the availability of substitute teachers while existing teachers extend their knowledge and teaching skills**.

At present, many see exactly the opposite happening - a shortage of current teachers overall means that there is pressure on time, and a lack of supply teachers. This in turn makes it difficult to obtain sufficient training to renew and extend the knowledge base and teaching skills of science and maths teachers. As already mentioned, weak teaching may contribute to continued difficulty in generating sufficient pupils taking science and maths A-levels and degrees, and continued difficulty in recruiting high quality graduates into teaching. Advocates of a greater emphasis on professional development argue that it offers a way out of this 'vicious spiral' but that it must be recognised that the resource demands for science and technology will be greater than for other subjects, and appropriate provision made. Another factor emphasised by some learned societies is that training and management should build on the strengths of the single science specialists, rather than attempting to turn everyone into a 'general science' teacher. Just as English (or history) teachers usually teach their subject rather than becoming 'humanities' teachers, it is argued that the amount of knowledge required in science still requires a collaboration between subject specialists who have the confidence to teach and inspire i**n their own subject**, whether it be physics, chemistry, biology, geology etc.

There is no shortage of written material for teachers who wish to be briefed on new developments, the role of science in industry and society, etc. Indeed a number of companies (e.g. Shell, ICI), learned societies (e.g. Royal Society of Chemistry, Institute of Physics) and organisations such as the Association for Science Education, have invested substantial sums of money in preparing and disseminating learning packs. Partly because of the amount of such material, and because of the finite time available to teachers to read it, some see **a need for better coordination between suppliers**. It has also been suggested that those prepared to fund further educational material might achieve more if they diverted such funds to support staff resources (e.g. helping supplement local coordination resources).

The **quality of teacher training** has also been under sustained scrutiny in recent years. Indeed, the government has just released proposals for a National Curriculum for ITT. From September 1997 (for primary English and Maths) and from September 1998 (for Secondary English, Maths and Science at all ages), the NC will set minimum requirements in ITT courses covering:-

- teachers' own knowledge of the subject;
- what their pupils should be taught;
- effective teaching and assessment methods, and how and when to use them;
- the standards of achievement teachers should expect of their pupils.

The TTA will take forward this work and define standards for all new teachers, to guarantee that whatever subjects they teach they can maintain discipline and teach effectively. The agency will also develop more subject specialist courses for primary teachers to address weaknesses in subject knowledge that have held back standards for the 8-11 age group (Key Stage 2).

The increased emphasis in subject content, however, follows a number of other trends which **are placing pressure on the subject content of training**. Mention has already been made of the trend to mixed A-levels, and combined honours degrees. The increased emphasis on school experience (and the associated fund transfers which go with it) are also reducing the subject content of PGCE courses. These conflicting pressures lead some to suggest that there needs to be an **explicit assessment of subject knowledge in the teacher qualification (in addition to the pedagogic qualification), together with an assessment of future priorities for professional development**. The TTA is working on a number of initiatives in these areas.

Finally, general concerns over the effectiveness of maths teaching have been exacerbated by the latest international survey (Section 2, Table 4) and fuel added to the

debate over **teaching methods**. Maths, along with English and history, have been the subjects most affected by the debate among educationalists over the balance between knowledge and accuracy on the one hand and skills and process on the other. Poor performance in tests and complaints by employers of poor numeracy after leaving school, lead to questions whether the National Curriculum needs to give **more emphasis to competency in the fundamentals of mathematics**. Research is underway to try and 'tease out' the influence of teaching style on the UK's declining international performance and is expected in Spring 1997.

## 9 IN SUMMARY

The above overview suggests that **there will be substantial difficulty in remedying current shortages of appropriately qualified science and maths teachers** in England - let alone meet the rapidly growing demand in the next decade. The position in Scotland appears less acute with less mismatch and better supply. However, the demographic picture is the same as in England and Wales, leading to a need to find increasing numbers wishing to enter training (especially in the priority subjects of maths and physics) in future years.

The difficulties described in this note are only the latest manifestation of underlying problems (shared by several other countries) stretching back a hundred or more years where a 'vicious spiral' (described above) has never been successfully broken. While there are many detailed reasons why high quality science and maths teaching presents particular challenges, **many see two key underlying ones to overcome**. One is the way many in society regard science and maths as separate rather than part of society as a whole, and treat these subjects as specialist pursuits for specialist jobs rather than as an essential grounding for life in a technologically advanced nation. The National Curriculum has broadened participation in science up to GCSE, but this has yet to spread to A-levels and beyond.

The second underlying problem is that policymakers find it difficult to appreciate the increasingly complex challenge of teaching modern science or maths when the pace of change is so great (and accelerating). One way of illustrating this would be to imagine teachers transported, say, from 1970 to the present day. In English, there would be the same language and most of literature would still be relevant; similarly for art, music, history etc. In science however, the old 'single science' teacher would find whole new fields having emerged from the fast-moving body of knowledge, much of it straddling traditional subject boundaries and requiring new concepts and basic knowledge to understand. The science teacher must also deal with new societal issues - e.g. on gene therapy, on foetal development, on global impacts of man's activities, so that new subjects are added to the teaching agenda without removing the need for the basic grounding in scientific knowledge and the scientific method. Equally the 1970 maths teacher would be unfamiliar with whole new branches such as chaos theory, topology, number theory - each of which requires a very different approach to the traditional algebra, arithmetic and geometry. Neither would many of the practical experiments which inspired earlier generations be compatible with modern health and safety regulations.

Thus, even though all subjects involve change and require training and support, science teaching inevitably entails more resources than other subjects[6] - from the challenges of ITT, through support while actually teaching (lab space, equipment) to a proper professional development through INSET. Experts in science education argue that **such assumptions should be built into the funding and other systems**.

Unfortunately the primary factors which have contributed to the current situation (limits on the numbers of suitably qualified initial trainees and a reluctance to consider teaching as a career by science graduates) are not readily resolved. Rather they require sustained commitment to many separate initiatives (such as those described above) which, though individually small, offer the prospect of cumulatively making progress.

Some raise generic issues for the teaching profession as a whole, for example:

- The status of the profession is an important factor in influencing who and how many apply for teaching. In this context, the critical importance of teachers and teaching (in preparing the next generation to live and contribute to 21 Century Society) could well be communicated better.
- Basic pay aside, there are questions whether there should be different pay rates for different subjects or at different pupil age levels to reflect the differences in challenge and difficulty.
- How to institutionalise professional development (e.g. the case for a General Teaching Council).
- Whether more account should be taken of needs for various subjects in HE expansion.
- How to ensure a level playing field for examinations so that standards and difficulty are comparable between science, maths and other subjects.
- Whether, given the accumulation of debt through student loans during the subject degree course, more financial encouragement needs to be given to graduates to embark on an additional year's postgraduate training for teaching in shortage subjects.

6. Where changes have occurred (e.g. in approaches to literary criticism), these do not generally have major material resource implications.

Others are specific to science:

- laboratory and other support,
- ability to update scientific knowledge,
- ability to build on the scientific expertise of one's choice (physicist etc.).

The persistence of the problem and the 'market failures' associated with devolving decisions to the schools (e.g. the local pressure on unit costs, so that it becomes more difficult for science teachers to obtain the necessary support in terms of equipment or technicians or release for training), also persuade many of a continued need for central policy in this area both from DfEE and the TTA. In the past (up to 1983), national fora existed which brought together teachers, industry and training institutions (e.g. the Advisory Committee on Supply and Training of Teachers) to address such issues. The TTA has an Advisory Group for Teaching as a Profession, and its recently established Teacher Supply Team may allow the agency **to bring together customers and suppliers and help generate a more strategic and holistic view of the needs of the overall system**. With the current emphasis on local management and markets and away from central planning however, some see an emerging need for regulation to ensure that schools assign a sufficient priority to delivering a high quality education in science, maths and other shortage subjects.

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## ACRONYMS

| | |
|---|---|
| ASE | Association of Science Education |
| BA | British Association |
| DES | Department of Education and Science |
| DfE | Department for Education |
| DfEE | Department for Education and Employment |
| E&W | England and Wales |
| EPSRC | Engineering and Physical Sciences Research Council |
| GEST | Grants for Education Support and Training |
| HEI | Higher Education Institutions |
| ITT | Initial Teacher Training |
| KS | Key Stage |
| LMS | Local Management of Schools |
| LT | Licensed Teacher (scheme) |
| MoD | Ministry of Defence |
| NC | National Curriculum |
| OFSTED | Office of Standards in Education |
| PGCE | Post-Graduate Certificate in Education |
| PPARC | Particle Physics and Astronomy Research Council |
| RE | Religious education |
| RS | Royal Society |
| SCITT | School-centred ITT |
| TASC | Teaching as a Career |
| TES | Times Education Supplement |
| TIMSS | Third International Mathematics and Science Study (Also F (first) and S (second)) |
| TT | Teacher training |
| TTA | Teacher Training Agency |