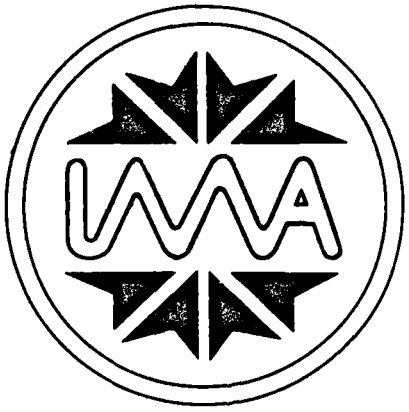
Box 1988

How to provide for the teaching of mathematics in secondary scho ls

The Royal Society and the Institute of Mathematics and its Applications 1988



How to provide for the teaching of mathematics in secondary schools

A report by the joint

Mathematical Education Committee

of

The Royal Society and
The Institute of Mathematics
and its Applications
1988

This report has been endorsed by the Council of the Royal Society.

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HOW TO PROVIDE FOR THE TEACHING OF MATHEMATICS IN SECONDARY SCHOOLS

PREFACE

This report was prepared by a working group of the Royal Society–Institute of Mathematics and its Applications Mathematical Education Joint Committee under the chairmanship of Professor C.A. Rogers, F.R.S. It deals with an issue that is important for everyone in the UK. Confidence in applying mathematical skills is important if each individual is to participate fully in, and feel comfortable with, our increasingly technological society. In a climate of a serious and worsening shortfall in the supply of good quality mathematics teachers, the teaching of mathematics in schools to pupils of all ages needs to be critically examined. Alternative strategies for teaching mathematics must be explored. The report considers a number of teaching strategies and spells out some specific recommendations for the work of a number of groups concerned with mathematics education.

How to provide for the teaching of mathematics in secondary schools is published with the commendation of Council to encourage debate among the many educationalists who are involved in some way in the teaching of mathematics, or are responsible for policy decisions affecting mathematics education. The Society's Council urges all in the education system to read and to comment on the report and to use its ideas as a basis to further develope their thoughts and actions.

Sir Roger Elliott, Vice-President and Physical Secretary, Royal Society

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SUMMARY

In an increasingly technological society, mathematics provides an important basis to many aspects of our daily lives. The quality of mathematical education at all levels has significant implications for the future well-being of the U.K. But the quality of mathematics teaching is dependent on the supply of enthusiastic, well-motivated teachers. It is disturbing, therefore, that evidence points to a serious and worsening shortfall in the supply of good quality mathematics teachers; a shortage, moreover, that cannot be overcome quickly even by an immediate increase in supply.

Three important courses of action must be followed if a disaster in the 1990s is to be averted: more qualified graduates must be persuaded to enter mathematics teaching as a rewarding career; more pupils must be encouraged to study mathematics into sixth form and further or higher education; and the expertise of existing mathematics teachers must be maximized. Those who go into mathematics teaching as a career must be given some grasp of how the mathematics they teach will be used in, for example, accountancy, commerce and economics as well as in the sciences and engineering. The report examines and recommends changes in the organization of teaching methods and of mathematical departments within schools, and between the distinct phases of the educational process, to eradicate any discontinuities and to make mathematics more accessible to pupils. Wherever possible the content of mathematics curricula at each level should be made more relevant to all the varied groups of pupils under instruction. The differing needs and perceptions of girls and boys should be recognized in mathematics teaching. This will require greater flexibility in the curriculum and in teaching styles than at present, more use of investigational and problem-solving activities, coursework and project work. The potential of resource-based teaching and computer-aided learning should add choice and variety to the learning of mathematics.

The staffing, teaching materials and departmental facilities that should be available in a good secondary school mathematics department are reassessed. In particular, the use of non-teaching assistants is advocated. The criteria traditionally assumed to influence whether students become mathematics teachers are challenged and more flexible prerequisites for initial teacher training courses are proposed, to cater for a greater potential pool of students. In-service training courses should be carefully designed to maximize the professional development of existing mathematics teachers. Considerable time, effort and resources are required to incorporate new ideas into mathematics teaching, but the pay-off will be worthwhile.

The report spells out the specific implications for the work of the following groups: classroom teachers of mathematics, secondary school heads of mathematics departments, secondary headteachers, LEA mathematics advisers and advisory teachers, teacher educators, the Secondary Examinations Council (SEC) and examination groups, LEAs, higher education (HE) admissions tutors, HE departments of mathematics, the Department of Education and Science (DES), and the professional mathematical associations.

If all the recommendations outlined in the report were implemented there would inevitably be an improvement in the way in which mathematics is taught in schools in years to come. It is also reasonable to assume that there would be a steady increase in the supply of good quality mathematics teachers thereby reversing the present chronic and worsening shortage. Growth in the pool of pupils with a firm mathematical education at all levels is vital to the technological needs of this country. We hope that this report will help that process.

1. INTRODUCTION

1.1. Mathematics is one of the most important subjects in the school curriculum. Much technology and many aspects of everyday life, industry, commerce, management and government are mathematics based. The maintenance and improvement of mathematics education at all levels is vital for the future well-being of the U.K. It depends upon having enough competent mathematics teachers at each level of education who can create an environment that promotes the learning of mathematics and who can pass on their enthusiasm. There is a serious problem of teacher supply throughout the physical science subjects. The shortage in mathematics teacher supply is chronic and worsening. The effects of this chronic shortage cannot be overcome by any immediate increase in supply. The number of people who completed teacher-training courses to teach mathematics in 1986 was half the number in 1976 (see section 2.1 on statistics). The outlook for the next decade is bleak.

1.2. Against this background the Mathematical Education Joint Committee of the Royal Society and the Institute of Mathematics and its Applications set up a working group to report on the situation. The working group was chaired by Professor C.A. Rogers, F.R.S. (University College London), and comprised Mr E.R. Ashley (Wootton Upper School), Dr A.J. Bishop (University of Cambridge), Dr D. Kerslake (Bristol Polytechnic), Mr D.W. Lingard (Northcliffe Comprehensive School), Dr J.H. Mason (Open University) and Mr H. Neill (Inner London Education Authority).

1.3. The working group's remit was (i) to assess the current and predicted shortage of mathematics teachers in secondary schools; (ii) to identify ways of remedying or alleviating any shortfall; (iii) to consider alternative means of teaching mathematics, given a shortfall; and (iv) to make recommendations.

1.4. This report is in four sections: (1) introduction; (2) background and perspectives, including statistical evidence, an international comparison, a survey of student teachers' perceptions of the teaching profession, and an account of some experienced teachers' perceptions of the teaching profession; (3) alternative strategies for mathematics teaching, in the form of the report of a workshop held at Sheffield City Polytechnic, 13–15 March 1987. The workshop was organized by the working group (see paragraph 1.2 above). The report of the workshop, which was edited by the working group, addresses the organization of educational institutions, changes in mathematical curricula and teaching styles, initial and in-service teacher training, human and physical resources in school mathematical departments, and resource-based mathematics teaching. Conclusions and recommendations (4) were added by the working group after the Sheffield workshop. Recommendations in the form of a checklist are aimed at classroom teachers of mathematics, heads of secondary school mathematics departments, headteachers, local education authority (LEA) mathematics advisers, mathematics advisory teachers, and teacher educators. Other recommendations are aimed at the Secondary Examinations Council (SEC) and examination boards, local education authorities, the Department of Education and Science (DES), higher education (HE) admissions tutors, university and polytechnic mathematics departments, and the professional mathematical associations. There are 3 appendixes as follows: the programme and the participants at the Sheffield workshop (A), a questionnaire put to student teachers (B), and a questionnaire put to experienced teachers (C).

1.5. In compiling this report the working party has been greatly helped by the chairmen and recorders at the Sheffield conference not all of whom were members of the group, namely Mr N.L. Biggs, Professor D.G. Crighton, Professor R.L.E. Schwarzenberger, Dr C. Shiu, Mrs A. Straker, Dr D. Woodrow and Dr W. Wynne-Willson. The working party offers its grateful thanks to these individuals, to the other participants at the conference, (listed in appendix A), and to others who helped in the collection of data, in particular the Department of Education and Science Statistics Branch.

1.6. The workshop on alternative strategies for mathematics teaching was supported by grants from the Royal Society and the Department of Education and Science, and the group expresses its thanks to these bodies for this support.

2. BACKGROUND AND PERSPECTIVES

Statistical background

2.01. The DES *Statistical Bulletin* 5/82 (March 1982) reports on the Secondary School Staffing Survey carried out on a sample of maintained secondary schools in England and Wales in the autumn of 1977. The following estimates come from tables 12–16 of this *Bulletin*.

TABLE 1. MAINTAINED SECONDARY SCHOOLS IN ENGLAND AND WALES; ESTIMATES OF THE NUMBER OF FULL-TIME EQUIVALENT TEACHERS OF MATHEMATICS HAVING THEIR HIGHEST QUALIFICATIONS IN VARIOUS SUBJECTS

subject of highest qualification	*estimated numbers*	
mathematics		18 400 (69%)
biology	700	
chemistry	800	
physics	1000	
other science	700	
total science		3200 (12%)
English	500	
history	700	
geography	800	
religious education	100	
French	100	
other languages	100	
total humanities		2300 (9%)
physical education	1200	
art/craft	300	
craft, design and technology	1100	
home economics	100	
music	200	
total practical and aesthetic		2900 (11%)
total non-maths		8400 (31%)
total		26 800
estimate of those with no recorded qualification in mathematics		3700 (14%)

NB Numbers do not total 100% owing to rounding.

The survey allowed each teacher to record one main subject and up to two subsidiary subjects of study in their training before becoming a teacher, and up to two further qualifications obtained after entering teaching. Thus some of the estimated 3700 teachers of mathematics (full-time equivalent) with no recorded qualifications in mathematics may have some subsidiary qualification in mathematics not recorded. Appendix I, table 16 of the Cockcroft report (1982) describes the mathematical qualifications of 21% of mathematics teachers in maintained secondary schools in 1977 as 'nil'. This is a matter of serious concern.

2.02. The DES *Statistical Bulletin* 8/86 for May 1986 reports on the Secondary Schools Staffing Survey carried out on a sample of maintained secondary schools in England in January 1984. The following estimates come from table 17 of that *Bulletin*.

TABLE 2. ESTIMATED NUMBERS OF MATHEMATICS TEACHERS (FULL-TIME EQUIVALENT), AMONG FULL-TIME TEACHERS, WITH VARIOUS RECORDED LEVELS OF QUALIFICATIONS IN MATHEMATICS IN MAINTAINED SECONDARY SCHOOLS IN ENGLAND IN JANUARY 1984

mathematics was the main subject of:		
honours degree or equivalent	5600	
Bachelor of Education (honours)	1000	
other degree or equivalent excluding BEd	3500	
Bachelor of Education (ordinary)	1000	
Certificate of Education or equivalent	5800	
other qualification	1000	
		17900 (72%)
mathematics was a subsidiary subject of qualification		3800 (15%)
mathematics was neither main nor subsidiary subject of a qualification		3300 (13%)
total		25000

Table 18 of the same *Bulletin* shows that in 1977 15% of the mathematics tuition was provided by teachers with no recorded qualification in mathematics and that in 1984, 13% of this tuition was so provided. This and the tables provide evidence of a substantial 'hidden' shortage of mathematics teachers, i.e. where mathematics is taught by teachers with inadequate qualifications in the subject.

2.03.The next table records the history of the training of mathematics specialist teachers since 1975, taken from an annual survey undertaken by the Royal Society; those for 1984 are missing because the Society collected no figures for that year.

TABLE 3. NUMBERS OF TRAINED GRADUATE AND NON-GRADUATE TEACHERS OF MATHEMATICS COMPLETING COURSES FOR TEACHING IN SECONDARY AND MIDDLE SCHOOLS

	type of course			
year	PGCE	BEd	non-graduate	total
1975	817	248	946	2011
1976	778	214	687	1679
1977	759	256	532	1547
1978	850	265	255	1370
1979	668	254	126	1048
1980	663	237	84	984
1981	755	198	40	993
1982	827	263	23	1113
1983	762	267	9	1038
1984	n.a.	n.a.	n.a.	n.a.
1985	650	242	37	929
1986	590	226	5	821
1987	621	218	0	839

2.04. A press release from the DES, dated 6 April 1987, contains encouraging information about the response to recent advertisements on teaching in the shortage subjects.

TABLE 4. RECRUITMENT TO INITIAL TEACHER TRAINING FOR MATHEMATICS: MARCH 1987

	target	applications by mid-March	intake
PGCE			
1986	942	686	741
1987	995	954	957
BEd			
1986	333	106	160
1987	390	139	237

Assuming that the mid-March figures represent new applications rather than applicants applying earlier than usual, these figures offer some hope of a significant reduction of the 'overt' shortage of teachers of mathematics (i.e. unfilled places for properly qualified teachers of mathematics). The DES *Statistical Bulletin* 1/87 reported 380 vacancies in England and Wales in January 1986. The much larger 'hidden' shortage and the unquantified 'suppressed' shortage (i.e. where curricular or organizational changes are made to avoid the need for mathematics teachers) developed over the decades and have been maintained by inadequate recruitment and retention of well-qualified mathematics teachers.

2.05. The DES has kindly provided details of the degrees of the graduates starting Post-Graduate Certificate of Education (PGCE) courses for secondary-school teachers of mathematics in 1984.

TABLE 5. FIRST DEGREES OF GRADUATES STARTING PGCE COURSES TO BECOME SECONDARY-SCHOOL TEACHERS OF MATHEMATICS IN 1984

degree subject	number of entrants expressed as a percentage of the total number of home and overseas, university and polytechnic graduates in 1984	percentage of total graduates in degree subject who enter PGCE courses
engineering and technology	72	0.5
*mathematical sciences	420	7.4
physical sciences	19	0.3
other science	8	0.1
economics	14	0.5
social science	12	0.05
arts, medicine and others	29	0.1
education	5	0.2
not recorded	60	–
total	639	

* 'Mathematical sciences' embodies mathematics, applied mathematics, computer sciences, numerical analysis, operational research and mathematical statistics.

Although the majority of these PGCE entrants have degrees in mathematical sciences, one third come with degrees in other subjects and some may not have a satisfactory

understanding of mathematics. Nevertheless, recruits with degrees in mathematically related subjects who are keen on mathematics should be welcomed and they should be actively recruited. We have not been able to obtain details of the mathematical qualifications of students entering BEd courses for mathematics teaching. However, in a small survey of nine BEd courses, done in 1987, the 150 sample students held, on average, over 8 O-levels. One third of the sample had at least grade A or B in A-level mathematics. More than 90% had more than the minimum requirement of two grade E A-levels. The average A-level point score of the whole sample was 5.8. These results were comparable with those of the students taking degrees in other subjects at the colleges and polytechnics used in the sample.

2.06. The next table, rather different in character from the previous tables, is taken from the DES 10% sample survey for 1984–85 for England (paragraph 2.02).

TABLE 6. THE INTENDED DESTINATIONS OF SCHOOL LEAVERS WITH A-LEVEL MATHEMATICS

1. Full-time or HE courses		
(*a*) *Degree courses*		
engineering and technology	6850	
mathematical science	2830	
physical science	3390	
other sciences	4350	
economics	1490	
social science, excluding economics	3810	
arts, medicine and others, but excluding education	3910	
not known	480	
total degree courses, but excluding BEd		27 100
(*b*) *Further education (FE) and other courses*		
Dip HE, HND/HNC, OND/ONC, GCE A-levels, GCE O-levels, City and Guilds	2140	
teacher training including BEd	410	
other accountancy	330	
miscellaneous	1850	
total other courses		4730
total full-time FE and HE courses		31 830
2. Employment	5870	
3. Temporary employment	3090	
4. Not known	1960	
total		42 740

It is remarkable that three quarters of school-leavers with A-level mathematics have intentions of proceeding to further education of some sort, over half to take degree courses in a wide variety of disciplines, most, but by no means all, where mathematics is a necessary or useful component. However, it suggests that the Government's recently announced target of an increased degree participation rate will not be attained by increasing the proportion of A-level mathematics students opting for FE or HE courses. It is essential to increase the proportion of students taking A-level mathematics. This can be done by improving the teaching of mathematics throughout the whole school system.

2.07. By combining data from *University statistics*, 1984–85, vol. 2, with data from *First destinations of polytechnic students qualifying in 1985* we obtain two tables giving information concerning the employment of mathematics graduates.

TABLE 7. FIRST DESTINATIONS OF UNIVERSITY AND CNAA GRADUATES IN MATHEMATICAL SCIENCES (BUT EXCLUDING MATHEMATICS WITH PHYSICS) IN THE UNITED KINGDOM IN 1985

destination	numbers	(%)
home students entering permanent employment	3511	(66)
others entering employment	126	(2)
academic research or study	502	(9)
teacher training	318	(6)
other (including law)	133	(3)
overseas students leaving the U.K.	298	(6)
not available for employment	73	(1)
*believed unemployed at 31 December	325	(6)
total graduates home and overseas, of known destination	5286	

* 'Believed unemployed' consists of those who are available for employment or study in the U.K. and have no firm arrangement to start employment or study before 31 March following the end of the academic year of qualifying.

The percentage of those of known destination who are believed to be unemployed (6%) compares favourably with the corresponding percentage (9%) for graduates in all subjects.

TABLE 8. TYPES OF WORK OF HOME STUDENTS GRADUATING IN MATHEMATICAL SCIENCES (BUT EXCLUDING MATHEMATICS WITH PHYSICS) WHO ENTER PERMANENT EMPLOYMENT

type of work	numbers	(%)
administration and operational management	105	(3)
scientific and engineering research, design and development	282	(8)
management services	2037	(58)
financial work (inc. accountancy)	822	(23)
other types of work	265	(8)
total	3511	

As can be seen, mathematical science graduates obtain work of many different types, but over half obtain work in 'management services'. This type of work includes: operational research, systems analysis, computer programming, data processing, organization and methods, work study, economics and statistics. All these jobs seem to require qualifications in one or more of mathematics, statistics or computer science; it is not surprising, therefore, that it is graduates of mathematical sciences that secure over half of the 4003 graduate placements in 'management services' jobs. This is an expanding area of employment, which has clear implications for the numbers of mathematics graduates available to enter other areas of work and, more significantly, to go into teacher training.

The international perspective

2.08. The circumstances that have led to the drastic shortage of mathematics teachers in England and Wales are peculiar to our society and to our education system. It is, however, desirable to put the situation in an international perspective; in particular, to establish whether other countries are in a similar position and whether the teacher shortage is a universal phenomenon. Accordingly, a letter was sent to the National Representatives of the International Commission on Mathematical Instruction (ICMI) in 58 countries enquiring about the situation in their respective countries. Replies were received from 27 countries, with some representatives sending very detailed information. The overall patterns that

emerge are especially interesting, and some particular solutions and strategies are also worthy of attention.

2.09. Most importantly, it emerged that teacher shortage in mathematics is *not* a universal phenomenon. Fifteen countries' representatives reported that they had a shortage—Australia, Botswana, Canada, Costa Rica, Denmark, India, Iran, Israel, Luxembourg, The Netherlands, Nigeria, Pakistan, Poland, Singapore and the U.S.A.—whereas eleven reported no significant shortage, or even a surplus—Argentina, Austria, F.R.G., Belgium, Brazil (São Paulo), Bulgaria, Cuba, Egypt, Republic of Ireland, South Korea and Switzerland. In the latter group there was, however, concern about teacher quality, and a recognition of the changing nature of subject demand, particularly in response to technological development.

2.10. The factors effecting teacher supply are diverse and interrelated and no single, clear explanation emerges. However, some aspects appear particularly significant.

(i) *Demographic trends.* Several respondents referred to the relation between the supply of, and demand for, teachers and variations in the birth rate. The relationship is complex but there is no doubt that it is a relevant factor and that solutions to teacher shortages will require accurate demographic predictions. Related to this is the increasing tendency of students to stay on longer in schools in several countries, thus creating more demand for specialized teacher expertise. The effect of demographic trends on the supply and demand for mathematics teachers needs to be taken into account. There is less control on planning in England and Wales than in some other countries, and market forces tend to dictate provision. The consequence is that even if students who wish to pursue mathematics are encouraged to do so, and are also persuaded to train as teachers (via the PGCE route), this will not necessarily generate the numbers of teachers required. Self- selection is thus inadequate on its own; a student-oriented option approach at school, university and career selection points cannot guarantee that enough mathematics teachers are generated. Of course the needs of the individual and the needs of society must always be balanced, but it is vital in the present context that other sources for teachers are identified, that teaching is perceived as an attractive option and that planning mechanisms adjust accordingly.

(ii) *Salaries and conditions of service.* In more centrally controlled economies than the U.K., or where teachers are part of the Civil Service, salary anomalies with other graduate employment either do not exist or do not contribute to the shortage. In those countries shortage is more likely to be a failure of planning and prediction. In 'less controlled' countries, competitive salaries do become increasingly important, as do teachers' working conditions. For example in Austria, Brazil, F.R.G., Switzerland and the Republic of Ireland, salaries and work conditions are reported to be relatively attractive compared with those in England and Wales and may help to account for the absence of a teacher shortage in those countries. It is essential to consider whether there are sufficient financial resources in the English and Welsh educational system at present to enable it to attract and retain sufficient numbers of teachers and if not, what should be done.

(iii) *The opportunity to study mathematics.* The encouragement, or discouragement, to study mathematics, among other factors, plays a significant role at various stages in a person's education in determining the final output of mathematics teachers. The ICMI Member for Brazil writes 'many people opt for mathematics because it is an easier possibility of getting a college degree'. Whatever the reasons for that statement being made, it raises important questions about the highly selective education system. In comparison with several other countries, we appear to make it difficult for students to continue their mathematical studies: entry standards to mathematics at A-level and higher education mathematics are high; the subject is hard; the narrow, selective and overly full content of A-level courses forces restrictive choices to be made against

mathematics early; university research demands still dominate university courses and the later years of secondary schooling; and the subject does not have an attractive image. It is clear that in many other countries more students study mathematics in some form for much longer than do students in the U.K. Of course, making A-level courses easier is only one way to attract more A-level mathematics students. A necessary precondition to attracting more people into mathematics teaching is to encourage more people to continue with mathematics as a subject of study.

Perceptions of the teaching profession

Perceptions of student teachers

2.11. In May 1986 a questionnaire (see appendix B) was distributed to teacher training institutions. It was designed to investigate the perceptions that student teachers had about the teaching profession and, in particular, teaching mathematics, at the end of their BEd or PGCE course training to teach mathematics. The response has been tabulated below. A total of 55 teacher training institutions were sent forms for distribution to students taking PGCE or BEd courses in mathematics (31 private sector and 24 public sector); replies were received from 43 institutions (27 private sector and 16 public sector). The total number of forms completed and returned by individual students was 596 (473 from private sector institutions and 123 from public sector institutions). The majority of the responses was from students preparing to teach in secondary schools.

TABLE 1. AGE AND SEX OF RECIPIENTS

	intending teaching					not intending teaching				
age	PGCE		BEd		total	PGCE		BEd		total
	m	f	m	f		m	f	m	f	
under 25	137	162	12	60	371	31	15	9	10	65
25–35	41	36	3	3	83	7	4	2	1	14
over 35	27	29	4	2	62	1	0	0	0	1
total	205	227	19	65	516	39	19	11	11	80

Intending teachers (tables 2–4). Total number of respondents 516.

TABLE 2. SCHOOL PREFERENCES

maintained	421	primary	38
independent	39	middle	13
both/either	47	secondary	440
other	9	other	25

TABLE 3. REASONS FOR CHOICE OF SCHOOL

area / location	164
type of teaching (age level, scope, sixth-form, etc.)	159
ethos of school (including political)	54
personal preference (including type of school they attended)	36
restricted to specific LEA	11
facilities (departmental, sports, etc.)	5
none given	87

TABLE 4. EMPLOYMENT IN TEACHING (AS AT MAY/JUNE 1986)

job confirmed	276
no job confirmed	240

intend to teach for:	1 year	2–5 years	over 5 years	other/don't know
	6	74	218	218

Non-intending teachers (tables 5–9). Total number of respondents 80.

TABLE 5. NUMBERS GRADING VARIOUS REASONS FOR OPTING NOT TO SEEK EMPLOYMENT IN TEACHING, ON A SCALE 1 (STRONG) TO 3 (WEAK)

	grading		
	1	2	3
pay levels too low	36	12	1
poor work conditions (including morale)	22	15	1
low status	27	16	2
too hard a job	3	10	2
little job satisfaction	10	6	3
too time consuming	7	9	2
few career prospects	12	8	2
other	32	1	0

TABLE 6. WHAT DO YOU INTEND TO DO NEXT YEAR?.

continuing education (including research)	13	engineering	4
accountancy	9	public service	4
travel	9	education-related work	4
management	7	armed forces	3
computing	6	insurance	1
religious/vocational work	4	don't know/other	16

TABLE 7. WHY DID YOU CHOOSE THIS JOB?

improved pay and prospects	18	better job satisfaction	7
can apply knowledge or training	10	religious/vocational reasons	4
travel	9	to widen experience (outside education system)	3
continue education	8	other	21

TABLE 8. WILL YOU RETURN TO TEACHING?

yes	no	possibly
33	30	17

TABLE 9. WHY HAVE YOU DECIDED TO DELAY ENTERING TEACHING?

need to broaden experience either in subject or generally	19	present conditions in teaching may improve	3
travel	8	family reasons	3
continuing education	6	other/blank	11

All respondents. Total 596.

TABLE 10. INCENTIVES TO INCREASE ENTRANTS TO TEACHER TRAINING AND TEACHING

	what would you do to increase the number of students entering maths teacher training courses?	what would you do to increase the number of student teachers entering maths teaching?
improve pay and conditions	314	410
pay higher grant or bonus	81	9
start on higher salary scales	3	10
alter teacher training courses	34	33
advertise teaching and teacher training courses	54	25
improve maths in schools (including syllabuses)	37	1
widen maths undergraduate courses	4	27
nothing/don't know	62	73
other	7	8

2.12. The following quotes are taken from some of the completed questionnaires:

On pay and conditions:

'Mathematics teachers...need...to have pay comparable to mathematicians in industry....too many potential maths teachers are drawn into industry where there is greater pay, and status and better working conditions.'

'So many of my friends say they would never teach because of the low pay. This is especially true for boys.'

On the status of the teaching profession:

'The teaching profession has lost a lot of respect over recent years and is considered by many people to be an easy job, done by those who are incapable of doing anything better. It is not even regarded as a profession by a large proportion of the public.'

On mature student teacher training grants:

'Mature students...often have heavy commitments, e.g. mortgages, children, etc., ... special provisions could be made for these cases.'

Against student grants:

'I would *not* offer more money to maths students on PGCE courses. This will increase the number taking the PGCE but will not result in a significant increase in maths teachers in the long run. Students will merely opt for the PGCE plus maybe a year or two teaching before finding a 'proper' job. Teachers need to be dedicated, not just in it for a few years for the extra money.'

On advertising teaching as a career to undergraduates:

'Run a recruitment drive on the milk round using cheese and wine buffets as bribery to compete with banks and accountancy firms.'

On advertising teaching posts better:

'Schools should give more information in advertisements and in the letter of acknowledgement ...they should use more constructive interview techniques.'

On discouragement encountered on teaching practice:

'I was continually sniped at for going from industry to teaching. 'Sane' people went the other way.'

'From family, friends and teachers I have worked with throughout my training, I have constantly had advice to do 'something better' and not 'waste my qualifications' on teaching. I have really felt it to be an uphill struggle trying to convince people that I actually *want* to teach and that I think I could gain satisfaction from it.'

On the lack of respect shown to teachers:

'Nowadays in many schools abusing teachers seems to be an acceptable pastime and anyone with any sense goes for a job where they are given more control and more protection than the average teacher.'

On teacher training courses:

'I ... think the role of teacher training courses should be one of enhancing a new style of teaching maths. Certainly those entering secondary schools need more than one term of professional instruction before their final teaching practice. From the first or second year, students need to be made more aware of the difficulties most people have in learning maths—particularly in secondary schools where maths is more formal.'

On mathematics teaching in schools:

'At present there is too much emphasis on maths teachers imparting the "required knowledge" for examinations, and not enough opportunity given for children to make sense of what they are learning, and so have a greater understanding and enjoyment of maths.'

Perceptions of experienced teachers

2.13. A small pilot study (questionnaire at appendix C) was done out to ascertain whether views of experienced teachers and student teachers were similar. The teachers were a biased sample weighted towards those undertaking courses of professional development. The sample was small ($n = 65$) with an average age of 35 years, an average scale post count of 2.3 and an average teaching life (to date) of 13 years. When asked if they anticipated that they would always be teaching, 48% said yes, and an equal number (48%) said no. It was somewhat disappointing that it was in general the younger teachers (average teaching life 10 years) who intended to leave the profession whereas the more established (average 15 years of service) would remain, in one or two cases somewhat reluctantly ('I don't see what else I could do'). It was also notable that 90% of all respondents were looking forward to early retirement, although they could be wishing to keep the option open rather than necessarily wanting the actuality.

2.14. When questioned about why they remained in the profession the overriding reason given was job satisfaction; working conditions (holidays) and status were next most significant. If they were to leave teaching the most likely reason would be working conditions (room, books, etc.) closely followed by salary and status. Nearly three quarters of respondents knew of mathematics colleagues who had recently left teaching and reported that over one third of them left because they were 'disenchanted' and nearly one third left because of better salaries outside teaching.

2.15. When they were asked what measures they thought would be likely to improve the recruitment of mathematics teachers, 50% mentioned pay increases with working conditions and improved status as the other major suggestions. Other comments of interest were the need to improve the enjoyment of mathematics for pupils, both in schools and universities, and to improve grants to mathematics teaching students to up to 90% of teaching starting salaries. Two responses indicated a positive intention to dissuade students from entering the profession at all. Given that those taking part in this survey were generally more motivated than the average teacher, this suggests that the discontent is even greater than the data indicate.

3. STRATEGIES FOR MATHEMATICAL EDUCATION

This section is a report of a workshop on strategies for mathematical education that was held at Sheffield City Polytechnic, 13–15 March 1987. The programme and participants' list is given at appendix A. The workshop took the form of a number of working groups. Paragraphs 3.03–3.81 contain reports on the discussions in these working groups edited by the organizing *ad hoc* group; the sections should be read as such and not as definitive statements.

I. Introduction

3.01. The DES consultative document *Action on teacher supply in mathematics, physics and technology* (HMSO July 1986) recognized that there was a shortage of suitably qualified and effective teachers of mathematics. Many organizations submitted responses to the consultative document to the Department, including the Royal Society, the Institute of Mathematics and its Applications, the Joint Mathematical Council, the Mathematical Association the Association of Teachers of Mathematics, the London Mathematical Society and the National Association of Teachers in Further and Higher Education. All of these responses suggested that the paper underestimated the seriousness of the shortfall of good quality mathematics teachers and that it was over-optimistic in its view of the future supply of teachers.

3.02. The purpose of the workshop was to give wider and deeper consideration to the ways of maintaining the teaching of mathematics, given the growing shortfall in the number of qualified mathematics teachers, and to bring forward more detailed and specific proposals. The workshop considered (*a*) changes in organization within schools, in curricular content, and in teaching styles to make mathematics more accessible, in particular, to girls; (*b*) increasing the use of computer-aided learning; (*c*) increasing the effectiveness of teachers by the use of more resources in the mathematics classroom; and (*d*) changes in the provision and requirements for initial and in-service training of teachers. There was a lot of constructive brainstorming at the workshop over what is an exceedingly complex problem. A number of proposals are expanded in this section. Some require immediate action, whereas others call for the initiation of longer-term investigations, many of which will need continued monitoring.

II. Institutional and classroom organization

3.03. There is a national shortage of mathematically qualified people that will worsen over the next 10 years as indicated by the statistics in paragraphs 2.01–2.07 of this report. If the supply of mathematics teachers is to be increased it is essential to enlarge the pool from which they are drawn. However, there are a number of discontinuities within the educational system where unnecessary hurdles deter or bar pupils from taking mathematics at the next stage. The current proposals by the Government to introduce attainment tests at ages 7, 11 and 14, to monitor pupils' progress within a nationally imposed curriculum, may add further disincentives for some pupils. Organizational changes in schools could remove these hurdles and encourage more pupils to enjoy mathematics and wish to continue with it. The working group addressed the ages of 11, 14, 16 and 18 because they are, for most pupils, the time when choices are made, or when significant changes in teaching style occur.

Discontinuity at age 11

3.04. There are several reasons why pupils become disenchanted with mathematics on changing from primary to secondary school. One major factor is likely to be the change in teaching style, or more accurately the learning/working style, that is adopted. This reflects the separate initial and in-service training of primary and secondary teachers; the two groups rarely meet. This is a significant contribution to the lack of continuity between primary and secondary phases and points to the need to develop real liaison between the two phases involving not just an exchange of information but a sharing of ideas, philosophies

and aims. Together the primary and secondary phases need to plan for an active, creative and positive approach to the learning of mathematics throughout the school years.

Discontinuity at age 14

3.05. At age 14 young people in our education system make their first significant choices in what they study in school. Although most pupils' curriculum will include mathematics, style and content of their courses can vary considerably. Steps should be taken to ensure that all pupils follow broadly based mathematics courses to 16+. These courses should be interesting, relevant to the learner, and allow scope for coordination with topics arising in other areas of the curriculum. Attention should therefore be paid to the role of the mathematics teacher within the whole curriculum, and the role of teachers of other subjects who also use mathematics within the context of their own subject.

3.06. The prospect and imminence of examinations often causes sudden changes in approach; these should be minimized as far as possible. In GCSE coursework development, all learning should continue to be based on earlier preparatory work with examinations as the culmination. Experimental approaches to assessment such as the Southern Examining Group (SEG) modular GCSE course, the Graded Assessment in Mathematics (GAIM) coursework-based GCSE, the Association of Teachers of Mathematics (ATM) coursework-based GCSE, and examples of mode 3 GCSE in some individual schools, should be encouraged by the Secondary Examinations Council (SEC) and the examination boards. The possibility of large combined coursework projects being submitted for assessment in more than one subject area should be explored. In any case coursework should be integral to the learning process and not a 'bolt-on' extra. Lessons should be drawn from experiments in modular curricula and skills-based approaches.

3.07. Almost all schools organize their mathematics teaching for this age group in setted groups. Setting in mathematics may lead to self-fulfilling prophecies as those in the top sets are encouraged to do well by their teachers and expect themselves to do so. Those in the bottom sets are encouraged less and have lower expectations, which can result in a sense of failure in their mathematics. Any organization of teaching groups must be flexible and be seen to be flexible by the pupils. It must pay attention to the different, often unpredictable, rates of development in mathematics learning, the differential rates of learning between topics, and the differences in learning style. Teaching groups should be flexibly structured, open to reconstruction and redefinition. Overall school organization should be such as to make decisions on levels of GCSE entry as late as possible.

Discontinuity at age 16

3.08. Most young people between 16 and 18 continue in some form of education or training in a school, an FE college, or a YTS course, etc. Unfortunately, too few of these young people continue to study mathematics.

(i) A significant group that stops studying mathematics is composed of those taking two or three A-levels not including mathematics, many of whom will have achieved grades A or B at 16+ mathematics.

(ii) Young people with a grade C at 16+ mathematics are often advised that they are less likely to have the same success in subsequent study in mathematics than those who have achieved the same grade in another subject and wish to pursue that subject further. There is currently little opportunity for pupils to change their minds after age 16.

(iii) There is evidence (see for example *Girls and mathematics*, RS–IMA 1986) that mathematics is regarded as a 'hard' subject, and this is supported by evidence that the grades achieved by students in mathematics are lower than those they achieve in other subjects. Mathematics certainly requires hard thinking, which can be very off-putting for some pupils. However, once mastered, concentrated thinking about mathematical problems and actually solving them, is a most rewarding experience. The perception of mathematics as hard seems particu-

larly to discourage girls from continuing to study mathematics, possibly because girls are less prepared to take the perceived risk of failing or of not doing very well. A reduction in the content of A-level syllabuses should encourage mastery of what is studied, and thereby increase confidence and achievement.

(iv) GCSE is intended to develop new styles of learning, in particular investigative work. This will increase students' expectations for their subsequent studies and have important implications for post-16 courses, in terms of their general approach, content and assessment. The recent establishment by the Secretary of State for Education and Science of a committee chaired by Dr G.R. Higginson to consider and review the principles that should govern A-level examinations, in the light of the implementation of the GCSE examinations, should not deflect from the urgency of our proposals. The deliberations of the Higginson committee may influence the effectiveness of some of our proposals; they are unlikely to make them any less necessary and desirable. In its response to the the Higginson committee, the Royal Society has drawn attention to this implication for teaching styles and assessment at A-level. Change will be particularly necessary in the present mathematics A-level.

If changes along the lines indicated above lead to more students studying mathematics post-16, then the added demand for teaching will, in the short-term, exacerbate the shortage of mathematics teachers. This should not detract from the important long-term benefits.

Discontinuity at age 18

3.09. At this stage of education the choice of courses is often perceived to be, and often actually is, irrevocable.

(i) The prerequisites for entry to specific courses are often rigid, and therefore constraining on 16–19 teaching in their demands. Attention should be paid to providing 're-start' opportunities in mathematics at all stages in education. There is also a place for 'access' courses to provide alternative ways of entry into existing courses for those without suitable qualifications. Shortage of recruits for engineering courses is already leading to alternative avenues of recruitment through, for example, Business and Technician Education Council (BTEC) courses. This may be capable of extension.

(ii) There is little possibility of transferring into mathematics-based courses without loss of time. Higher education institutions should find ways of allowing transfer between courses, at least throughout the first year of courses.

There is considerable risk to a student who commits him or herself to a degree course in mathematics as it is possible to fail at every stage without recourse to alternative options. Ways of teaching and assessing mathematics at this level should be explored to find ways of minimizing this risk.

3.10. The possible advantage to individual students of taking 'double mathematics' A-levels (mathematics and further mathematics, pure and applied mathematics, or other combinations) is now outweighed by the disadvantages for the community, especially as they will be joined on honours mathematics courses by others with single mathematics A-level. If double mathematics were no longer offered at 18+, this would release well-qualified mathematics teachers to teach elsewhere, allow students to broaden their studies, and encourage students with a single mathematics A-level not to consider themselves at a disadvantage, and thus to apply for an honours mathematics course. Although universities and polytechnics have a part to play in making clear that double mathematics is not a necessary entry requirement, it would be essential that examination boards should cease to offer such syllabuses, because as long as they exist they are perceived as desirable.

Possible areas of research

3.11. The hurdles described above are a real cause for concern. There has been some research on the influence that these hurdles might have on mathematics teaching, and other research is in progress, mainly in the field of attitudes to mathematics. It does, however, appear to leave many important questions unanswered, especially:

(i) More information is needed about whether there is an appreciable change in attitude to mathematics as pupils transfer from primary to secondary school. Do they feel that their secondary-school work developed from their primary school experience, or was there a discontinuity in the style of teaching, or a change in the nature of mathematics? Was the mathematical experience with which they arrived still valued? Is what was seen to be important in the primary school still important in the secondary, or are there different and unexplained expectations? Did their primary school experience (particularly scheme-based courses) equip them for transfer to secondary school? These issues are discussed in some detail in *Girls and mathematics* (RS–IMA 1986).

(ii) Many young people who have been quite successful at mathematics at O-level (or, presumably, GCSE) choose not to continue their mathematical studies. It would be helpful to find out why these pupils opt out of mathematics. In particular, there should be an attempt to find how they perceive their mathematics education so far, what they think an A-level (or AS-level) course would be like, and why they reject it. There is evidence to suggest (see paragraph 3.08 (iii)), that A-level mathematics is seen as a 'hard' subject and that, therefore, it is a risky one to choose.

(iii) Choices made at age 18 (and probably also those made earlier) are usually irrevocable. It has been suggested that, as for A-level, a mathematics degree is perceived as 'hard' and therefore a risky one to embark on. It should be possible to establish whether this is a serious factor in the choice young people make at this stage.

III. Mathematical curricula

Increasing the pool of people qualified in mathematics

3.12. As already stated (paragraph 3.03), it is essential to increase the size of the pool from which new mathematics teachers can be recruited. In this context a critical examination of the appropriateness of mathematical curricula and methods of assessment, especially at A-level and in higher education, is now urgent.

3.13. If the numbers entering HE are to be increased, then mathematics courses must be available to students who have covered markedly less mathematics by the age of 16 than is traditionally the case. In particular, those gaining good grades on GCSE intermediate papers must be able to go on to advanced courses such as AS-level or A-level. Such students will have covered little more than list 2 in the mathematics national criteria determined by the SEC.

3.14. The content of HE courses will also need revision. Some years ago a study by R. McClone (*The training of mathematicians*, SSRC 1973) showed that graduate mathematicians who went into industry seldom used any mathematics from third-year degree work. This suggests that some first degree courses could have less content than at present. If the content of a first degree course were reduced, then the entry requirements for degree courses could be more flexible, thus taking some pressure off A-level courses.

3.15. The requirements for engineering and physics HE courses are already changing in response to the greater academic variety of the background of entrants. These changes will need to continue so as to take account of new A- level courses which encourage greater understanding of less topics. Changes in A-level courses should not entail a lowering of standards. The intellectual demands of the highest grades at A-level and in degree courses should be as high as at present, notwithstanding the reduction in content.

The relevance of the mathematics curriculum to particular groups

3.16. Increasing the pool of qualified young people will require mathematics to be more appealing for groups of pupils who have traditionally found it unattractive or difficult. Many girls perceive mathematics in an unfavourable light. The case for making mathematics more appealing to girls, particularly at the advanced levels of schooling, is clear in the report *Girls and mathematics* (RS–IMA 1986). That report notes the need to remove gender bias (and by implication cultural and racial bias as well) from course materials, as well as the need to incorporate cooperative work in the context of problem-solving and experimentation. Another important suggestion is that the sixth-form timetable should allow for an A-level mathematics option within a very broad range of A-level subject choices. Future reports on examinations should indicate progress (or lack of progress) in this area.

3.17. Far more is necessary than the 'removal of bias' and the 'inclusion of more problem solving and group/cooperative work' in curriculum development. The curriculum post-16 needs careful scrutiny as to its suitability for, and its ability to motivate, very different groups of pupils. The uses of mathematics extend well beyond sciences. Mathematics is closely tied with careers in accountancy, commerce, economics and engineering. This will require greater flexibility within the curriculum than at present. Some flexibility is offered at the 16–18 level through the provision of AS-levels, but that may not go far enough. More consideration needs to be given to the question of how to provide a wider range of mathematics options, both within the mathematics A-level syllabus and in terms of links with other subjects. One idea deserving consideration is a modular approach to A-level courses, to provide students and teachers with the opportunity to be selective and so tailor the course to the needs and interests of the individual and group.

Broadening the view of mathematics

3.18. An important way to make mathematics more accessible to more pupils is to broaden the view of mathematics as a curriculum subject. Typically, many people perceive mathematics as narrow, hard and 'cold'. This view contributes to many students' reluctance to continue the subject beyond the compulsory stage. Fortunately, there are already some developments, such as the introduction of calculators, geared to making mathematics a more 'user-friendly' subject. Investigative activities, coursework and project work also give the opportunity for mathematical activity of a more personally satisfying nature than do traditional approaches to the subject. These activities enable students to see the relevance and use of the mathematics that they are learning to other areas of activity more clearly.

3.19. The nature of mathematics as a study of abstract concepts can result in it being perceived as a dehumanized curriculum subject (with little reference to people). There are three suggested remedies for this:

(*a*) The introduction into the mathematics curriculum of *historical* contexts has been frequently recommended, but rarely acted upon. Of particular importance are aspects that relate to mathematicians as people, properly integrated throughout the mathematics curriculum. 'Pythagoras' is a theorem to most young people: they are given little idea of the lives of the people whose names are associated with such famous results.

(*b*) The *societal* role of mathematics has received some consideration in recent years: for example, the place of a mathematical view of society, the effect on peoples' lives of a quantitative approach to problems, and the moral questions posed by the use of mathematics in relation to technological developments (which may have good or bad repercussions).

(*c*) A *multi-cultural* approach to the mathematics curriculum is beginning to be seen by many educators as having great potential significance. This approach offers arguably the best framework for humanizing the mathematics curriculum, as it encompasses both historical and societal aspects. Mathematics presented as a phenomenon that all cultures develop and engage in illustrates perfectly the human relationship with the subject: for example, working with different counting and measuring systems, exp-

laining alternative approaches to location and orientation, analysing the significance of different shapes and designs, and playing mathematical games from other cultures.

3.20. Finally, there is concern about the overall perception of mathematics that the present curriculum fosters. Mathematics comprises a powerful set of conceptual structures capable of explaining broad ranges of phenomena, but it is rarely presented as such. Typically, the perception of mathematics in the minds of most people is of a large collection of unrelated facts and techniques, most of which have no relation with their lives at all. It is essential for this image to be redressed to improve the accessibility of mathematics for the majority of the population.

The content of the mathematical curriculum in schools

3.21. Changes in the content of the curriculum are inevitable if school mathematics is to reflect accurately the nature of the subject as practised today in industry and commerce. The subject is developing rapidly and the pressure for change is strong. In an ideal situation the existence of a revitalized curriculum should, in itself, help to attract new teachers. But the dangers of top-down development are well-known, and these dangers are exacerbated by the shortage of teachers and the low morale of the profession. The long-term support of the DES and the LEAs is essential if teachers are not to become totally discouraged by the new demands being placed upon them.

3.22. A major impetus for change is the growth of information technology. The potential of computers as teaching aids has been widely recognized; indeed computers do offer some prospects for using teachers' time more efficiently. In the long term, however, there will be a more far-reaching impact on the curriculum itself. The algorithmic viewpoint will become more widespread, and discrete mathematics correspondingly more important. The need for research and development in these areas of the curriculum is urgent. Concurrently, the problem of pruning current syllabuses must be faced, especially at sixth-form level.

3.23. A related issue is the incorporation of simple computer programming, such as LOGO, and computer packages into the mathematics curriculum. Existing computer studies courses in schools have tended to present a non-mathematical, or even anti-mathematical approach, leading to an artificial and damaging division between mathematics and computer science. The integration of computer programming in the mathematics curriculum will require a major curriculum development initiative and substantial funding.

3.24. It is difficult to define what is meant by the expression 'teaching style'. The stereotyped view of the school teacher is of a person who stands at the front of a class, in full control of the activity of each student all the time. This view is mistaken in the case of many classrooms and it is being challenged for a number of reasons:

(i) the recognition that there is a wide variation in the attainment of the students in the class, even when the class is quite carefully setted;
(ii) the increased use of inquiry, investigation, discussion, practical work, extended tasks and cooperative group work;
(iii) the growing feeling that if students were more involved in determining the direction of their own learning they would learn more, a partnership in learning would develop and more responsibility would lie with the student;
(iv) the increasing prevalence of teaching styles that provide mutual respect between teacher and students and let students know what the teacher is doing in the classroom and why;
(v) the increased use of resource-based learning;
(vi) the recognition that challenge is more appropriate than 'spoon-feeding'; and
(vii) the introduction of GCSE.

3.25. Changes in the structure, as well as the content, of the 16–18 course could improve its breadth and flexibility. But there will always be conflict between the wish to broaden studies and the need to provide the basic mathematical skills. The question of core

studies, and the role that such a core should play in the overall design of post-16 proposals in mathematics, is likely to remain whatever changes are made.

3.26. There are arguments for the introduction of an A-level mathematics course that has a different balance between content and process from that in current courses. Such a course would allow time for activities such as problem solving and projects/ assignments, thus providing the opportunity to consolidate understanding. If such an A-level could also provide the relevant underpinning for degree programmes in the physical and biological sciences, engineering, business studies, computer science and the mathematical sciences, then it would increase the pool of mathematically qualified students entering HE.

The content of mathematical courses in HE

3.27. A worrying proportion of students embarking on degree courses in mathematics do not complete the course. Anecdotal evidence suggests that in some institutions as many as 20–30% of students will be lost during the three years. Some of these students move to other courses in HE, but it is rare for students to move from other subjects into mathematics. One common cause for disaffection is that students feel that they have only been able to understand a very small fraction of what is presented to them. If interest and motivation are to be maintained, students need to feel that they are being successful; this is just as true in higher education as it is in primary school.

3.28. Even among those who complete mathematics degree courses successfully there are many who have lost their interest in and enthusiasm for the subject. Too many students with high A-level grades go to university or polytechnic full of enthusiasm for mathematics (and possibly intending to teach it) and emerge three years later disenchanted. This may be one reason why mathematics degree courses have a reputation for being difficult. In consequence, sixth-form students with the ability to study mathematics in higher education are tempted to choose other subjects, simply because they are perceived as easier.

3.29. Many of those who have shown that they have the necessary mathematics aptitude at A-level, and who consider taking mathematics degrees, are deterred from the attempt, or start and drop out, or finish but are put off mathematics for life. A conservative estimate is that the number of such people is equal to 20% of mathematics graduates.

Initial teacher training

3.30. It is necessary to examine the traditional criteria that are assumed to influence whether students become teachers of mathematics. Unless salaries are increased to a more competitive level it is unlikely that a significantly higher number than at present will opt to enter the teaching profession.

3.31. Having a degree is a prerequisite for all teachers; whether it is necessary for teachers of mathematics to have specialized in mathematics is debatable, although no one would deny the importance of a sound mathematical background. Although the traditional assumption is that most secondary mathematics teachers are mathematical specialists, in fact many have different qualifications. The content of most first degree courses in mathematics has little relevance to the 11–16 school curriculum; it has only minor relevance at A-level. Recent changes in the requirements of the Council of the Accreditation of Teacher Education (CATE) are likely to make this increasingly the case for BEd degrees, too, in which the mathematics in the main subject becomes increasingly divorced from the school curriculum, especially for primary teaching.

3.32. Students with a broad range of HE qualifications must be recruited into teaching; their mathematical knowledge and maturity can be turned to good use in the classroom. Much more positive effort should be made to recruit intending teachers of mathematics from those whose degree qualifications are in geography, economics, engineering, in newer subjects such as telecommunications or information science, and also those with joint honours degrees such as mathematics with music. It is preferable that a graduate in one of these subjects should directly enter mathematics teaching through a PGCE mathematics course, rather than through some other PGCE course followed by a later move to mathematics teaching in response to the pressures created by the shortage. University and polytechnic lecturers should encourage second and third year degree students of these subjects to con-

sider the advantages of teaching mathematics. The early professional development of teachers trained to teach mathematics with a degree in another subject would be enhanced by appropriate in-service support.

3.33. Another way to increase the pool from which potential teachers can be drawn is to modify minimum entry qualifications for initial teacher training courses as follows:

(i) For BEd (4 year): grade A, B or C in GCSE mathematics; and 2 A-level passes (which may not include mathematics). This has implications for the design of the mathematics components of BEd courses.
(ii) For BEd (2 years): BTEC higher or overseas qualifications in a numerate area not currently recognized as degree equivalent.
(iii) For PGCE (2 years): grade A, B or C in GCSE mathematics; and a degree (or equivalent) in a non-numerate area.
(iv) For PGCE (1 year): a degree (or equivalent) in a numerate area for first *and* second method courses.

3.34. These conditions are in some respects less demanding than those recently laid down by CATE. The CATE guidelines prevent some quite capable candidates from entering training courses. Moreover, the emphasis that the CATE requirements place on the teaching of the subject reduces the time for the teaching of method in primary BEd courses; this is likely to decrease the mathematical confidence of primary student teachers. A short-term increase in the availability of suitable courses is likely in light of current initiatives by the Manpower Services Commission (MSC), the DES, the University Grants Committee (UGC), and the National Advisory Board (NAB). If these initiatives are to be effective in the long term, they must be coordinated and built upon. There is need for the provision of:

(*a*) taster courses to give potential entrants insight into teaching and information about courses and funding (current pilot courses involve about 20 participants in a one-week programme of activities conducted by two tutors);
(*b*) more positive promotion of teaching as a career to undergraduate students and potential mature entrants, supported by greatly improved facilities for gaining further information and advice about a teaching career;
(*c*) programmes giving undergraduate students opportunities to participate in activities with teachers and pupils in schools, analogous to the opportunities now widely available in other career areas.

3.35. The lack of funding and support for students must not act as a deterrent to potential teachers. There should be:

(i) removal of the parental means test on all grants for professional teacher training covering one or two year courses, and the last year of four year education courses;
(ii) a grant equivalent to the take-home pay of the first-year salary in teaching for mature students (defined as those out of full-time education for at least three years);
(iii) provision for part-time teacher training courses with appropriate funding (for example, for a supporting teacher/tutor);
(iv) entitlement to full financial support to take approved mathematics credits with the Open University, or through similar provision by other higher education institutions, before embarking on professional teacher training;
(v) provision for mature entrants to receive appropriate salary increments to reflect other relevant experience.

3.36. The recently imposed teacher pay scales seem to have removed the right of entrants to be credited with increments for relevant related experience such as working in industry or bringing up a family. If this is so it will sharply reduce the attraction of teaching for many mature entrants: it is of vital importance to restore these increments.

IV. In-service education and training (INSET)

Needs

3.37. In-service education and training should be regarded as professional development and not merely as the rectification of deficiencies. In-service training should be school-focused whether the course be school-based or external. There should be a balance between school-based and institute-based training. Teachers often benefit from the stimulus of INSET and the time and opportunity it provides to reflect together on some common question. School-based in-service training where two teachers are working together only requires cover for one of them.

3.38. Some teachers feel threatened by the challenges of changing teaching styles (although, of course, many others will welcome them). Most of the changes pull in a roughly similar direction, which perhaps makes the threat greater. There are a number of reasons why teachers worry about the direction of these changes, and why things get in the way of these changes, assuming that they are desirable:

(*a*) There is a great fear of the unknown. When a 'successful' teaching method has produced adequate examination results, it is difficult to argue for change.
(*b*) There is a fear of losing control. When students are doing a wide variety of different tasks in the same room some teachers are concerned that disruption will ensue. Greater pupil involvement will mean a noisier classroom.
(*c*) There is an apprehension of yet more extra work, in particular, that lesson planning will be made more difficult, that record keeping will be horrendous, and that marking will take longer.

3.39. There are a number of specific needs perceived by teachers at the present time. One is the need to integrate the use of the microcomputer into mathematics teaching, and this may sometimes involve specific training on a specific aspect of the technology. A more diffuse, but equally pressing, need is the opportunity to work reflectively on teaching styles, especially in the light of the demands of GCSE. The development of the skills needed for resource-based teaching is a high priority here; there is a lot of resource material arriving in schools, but ways of using it are not self-evident and INSET back-up must be provided.

3.40. A rather different form of professional development, which could have a very beneficial effect in the longer term, is the improvement of the public image of mathematics and mathematicians. A recent newsletter by the Joint Mathematical Council (JMC) has described a number of initiatives in this area.

Provision

3.41. The new INSET funding under the Grant-Related In-Service Training scheme aimed to provide the means for LEAs to plan teachers' needs for INSET work. Unfortunately, one outcome has been a large reduction in the number of opportunities to take longer courses, of say one year duration. This may be particularly serious in mathematics, both because of re-training needs and because of the need to motivate those with mathematics qualifications to stay in teaching. Indications are that special arrangements will be made, but it remains to be seen whether these will be adequate.

3.42. The lack of suitable supply teachers makes the provision of INSET difficult. Wherever possible, staff allocation in schools should be allowed to increase to provide for permanently available cover for teachers on courses, without disruption to the timetable. Another possibility is to run courses at weekends and in holidays and to pay overtime to those who attend, using the money that would have been needed for cover had the courses been run during working hours.

3.43. Collaboration between LEAs, local institutions and the Open University (OU) should be fostered and supported. The support provided by advisory teachers, funded by the Education Support Grant (ESG), has been found extremely valuable. It is essential that a way be found of continuing funding for this provision.

3.44. To make the best use of available resources there needs to be good liaison between the various providers of INSET (e.g. LEAs, universities, polytechnics, the OU,

advisory teachers and the professional mathematical associations) and a clearly thought out long-term plan for the various inputs. The recent provision by NAB (to polytechnics) and the UGC (to the universities) for courses to help with the supply of mathematics teachers, was arranged hastily. This has undoubtedly led to a less than optimal arrangement and waste because there was no time to avoid overlapping and duplication of effort. In addition, resources that have been made available to set up courses and provide the appropriate teaching materials have been wasted when retraining courses have been cancelled because no money was released for supply cover.

3.45. The professional mathematical associations have an important role to play in providing INSET both through working groups, which benefit the teachers directly involved and produce materials of use to others, and also through the courses and conferences they run. However, as voluntary organizations, they are not well resourced. It is interesting to note that teachers often perceive a need for INSET, and organize suitable events in their own time, through local branches of the associations. Quite small specific grants from external sources can generate substantial activity. SMP 11–16 is also active with over 60 user-groups that have sprung up of their own accord (or with some LEA prompting and support). There is also a further mathematics user-group.

Incentives

3.46. The major incentive for teachers to participate in INSET activities is, quite properly, the desire to improve both their professional skills and their career prospects. It is essential not only that appropriate INSET is available but also that it is accompanied by specific career advice. Such advice will usually come from the advisory team. This is discussed further in paragraphs 3.30–3.36.

V. Resources in schools

Personnel

Effective use of part-time teachers of mathematics

3.47. There are three distinct types of part-time mathematics teachers:

(i) *The part-time teacher of mathematics.* This would be a teacher who is properly and fully qualified to teach mathematics and who comes into the school for a few days (or half days) each week to teach only mathematics. This may be, for example, because of young children at home or perhaps someone who is studying for a part-time degree. Such a teacher may share classes with other teachers and is likely to be paid on a scale 1 salary in most local authorities. It is uncommon for such teachers to be promoted beyond scale 1 and ways round this need to be found. It should be possible for such a part-time teacher to be promoted beyond scale 1 when their contribution to the mathematics teaching so merits. However, the practical difficulties posed by part-time teachers holding paid positions of responsibility are appreciated. Nevertheless, attention needs to be given to the career development of this valuable resource.

(ii) *The full-time teacher who teaches mathematics for only part of the time.* This could be the teacher whose main subject is, for example, geography, but who teaches one or two classes for mathematics. Such a teacher could be on any scale, but if on a high scale is likely to have other responsibilities.

(iii) *Teachers who share between them a full-time post.* This could be two teachers who between them share one set of classes. Together they are equivalent to one full-time teacher, and they might have a responsibility allowance for mathematics.

3.48. There is a substantial number of fully trained mathematics teachers who are not currently employed as teachers. It is a reasonable assumption that a proportion of these would welcome the opportunity to return to teaching part-time if it suited their circumstances, and they are a national resource that is not being adequately tapped. There are

certain difficulties at present in employing part-timers, but there is no reason to suppose that schools would be unwilling to employ part-timers if suitable arrangements could be made. This is particularly important when experience has shown that many teachers who do return to teach part-time eventually become full-time teachers. A part-timer dedicated to teaching mathematics may often make a greater contribution to a mathematics department than the equivalent time proportion of a full-timer with other commitments within the school.

3.49. People who are prepared to be part-time teachers of mathematics may not always realize that job opportunities exist for them. Information as to their whereabouts could be collected on a local basis. They are unlikely to read the journals in which job advertisements are usually placed, and imaginative advertising is therefore required to reach these prospective teachers. Advertising on local radio, in the local free press or in the corner shop may be surprisingly effective in these cases. A letter to parents from the head-teacher may also be fruitful. Such a campaign could produce a national register of potential part-time teachers.

3.50. Full-time teachers who only teach mathematics for part of the time are not difficult to locate because they are already in the school. They are usually asked to teach mathematics to fill what would otherwise be a 'hole' in the timetable. It may be more difficult, however, for a teacher who is prepared to share a job to find a partner with whom to share. LEAs may find it helpful to keep a register of teachers who wish to job-share, and to advertise that the register exists.

Deployment within the department

3.51. Part-time teachers who can be flexible about the days or half days that they work can give flexibility to the department's timetable. On the other hand part-timers can add to the organizational load of full-time staff. It can sometimes be difficult to make a suitable timetable for the part-timer because the school timetable already exists and cannot be negotiated to fit the days that the teacher is available. In this case the mathematics department may need to be creative and flexible to make the best use of the part-time teacher resource. Furthermore, the way in which teachers of mathematics are organized to teach mathematics in the school needs to be efficient and effective. 'Geography' teachers who are drafted to teach mathematics may not always be deployed in ways that maximize their strengths. It is all too common for such teachers to be given difficult classes to teach and the opportunity to exploit the cross-curricular potential is not often taken. There are not usually problems in deploying teachers who job-share, but it may be necessary to build in meeting or discussion time between the job-sharers.

Integration and support

3.52. A returning teacher who is contemplating taking a part-time position may need a short refresher course; this should be provided by the LEA. After returning, some teachers have reported that they feel isolated and lonely; it must be the responsibility of all the members of the department, and in particular the head of department, to make them feel valued. Meetings should be arranged at convenient times for all the department, and suitable accommodation and work space be provided. Similar issues can arise with the other types of part-time teachers. Part-timers may also be vulnerable to changing circumstances within the school. Falling rolls can mean declining staff numbers and it can be tempting for the suggestion to be made that it is the part-timer who is redeployed. It is up to the local authority to organize better job security for the part-timer. This may require a reappraisal of policies and employment attitudes.

Provision and requirements for retraining courses

3.53. Courses for teachers who were previously trained to teach subjects other than mathematics fall into two groups: those who are currently employed as teachers in another subject area, and those who have left teaching and wish to return with new skills. This is an important potential pool of teachers that can provide an expertise in the application of mathematics in other subjects, followed by pupils aiming for a variety of careers. There can

be no satisfactory 'quick' retraining courses. Participants need opportunities to learn some mathematics, and time to reflect on their learning so as to analyse the implications for teaching mathematics. One year is a minimum length of time and secondments must reflect this.

3.54. The main criterion for recruitment to retraining courses should be motivation and commitment to the proposed career move. The recruits will generally have had successful teaching experience in their original subjects. LEA advisers are likely to be in a strong position to advise the trainers on suitable candidates. For returning teachers a taster course of, say, one week duration can give the flavour of what mathematics teaching is like now (or at least what it can be like).

3.55. The career implications for all potential recruits must be considered before they embark on such a change. It must be recognized that they may be at a disadvantage with regard to promotion prospects, compared with young teachers coming directly into mathematics. Schools releasing teachers for retraining need to consider beforehand how they may best be employed after the training. It may be appropriate to guarantee that the retrained teacher will be employed teaching mathematics, and not their former subject. It can be very difficult to keep abreast of two teaching subjects, though teachers qualified in two areas can make an invaluable contribution to cross-curricular planning and provision in schools. In some cases it may be appropriate for the LEA to organize a satisfactory redeployment.

3.56. Teachers need to see the benefits of retraining, e.g. increased job satisfaction, and the availability of resources to do a professional job. Furthermore, there must be adequate financial support during the retraining period. Former teachers of other subjects who have left teaching and are considering returning will be encouraged by the possiblity of salaried retraining. Many potential recruits can only undertake retraining if they have salaried secondment, yet this is a heavy burden on LEA in-service resources.

3.57. The pool of potential returners includes married women who have left teaching for family reasons. Here, incentives might include the possibility of *secure* part-time employment, job-sharing, with promotion prospects, and child-care facilities during training and in employment.

3.58. The immediate prospect is that a number of institutions are in a position to mount appropriate courses, and significant numbers of serving teachers are interested in taking these. However, the new financial arrangements for in-service training under the GRIST scheme have meant that LEAs have sharply reduced the number of secondments. To ameliorate this situation LEAs could, for example, be given specific grants, equivalent to scale 1 salaries towards the cost of releasing each retrainee.

Non-teaching assistants in the school mathematics department

3.59. Improvements in the facilities for mathematics teaching are necessary not only for the sake of the pupils, but also to retain existing teachers and to keep up their morale. Over the last decade there have been significant developments in mathematics teaching towards more resource-based teaching methods. The provision of technical non-teaching assistants in the mathematics classroom, of the kind common in science or CDT departments, is now necessary for the mathematics department to run smoothly and efficiently.

3.60. Resource-based learning has arisen from the use of individualized programmes of work and the welcome move towards a more practical, investigational and problem-solving approach to mathematics teaching. This requires a variety of small mathematical equipment, the management of complex filing systems and records, and the organization of computer hardware and software. These developments have been intensified by the advent of GCSE with its emphasis on practical and course work.

3.61. At present mathematics teachers organize their own resources. However, the increasing pressure on teachers imposed by these non-teaching duties has been one of the factors reported in diminishing job satisfaction among mathematics teachers, which is exemplified by the increasing wastage rate among them. Many mathematics teachers feel increasingly frustrated by the limitations on curriculum development brought about by a constraint on time partly caused by their additional non-specialist chores.

3.62. Heads of departments in the few schools where ancillary help exists suggest a number of helpful developments that have occurred.

(i) There has been less staff absence among the other teaching staff.
(ii) The visual learning environment has been made more stimulating.
(iii) Worksheets have been produced more efficiently.
(iv) Mathematics teachers have been able to spend more time on the preparation, organization and assessment of pupil's work.
(v) A central location for expensive equipment, such as microcomputers, has allowed access by pupils in the absence of a teacher, but in the presence of an adult.
(vi) Coordination within the department has reduced the duplication of equipment.
(vii) More of the teacher's time has been used for teaching because the classroom resources are organized more efficiently.

3.63. Technical assistants clearly improve the working conditions within a mathematics department. This should encourage mathematics teachers to remain within the profession. Indeed, such support is taken for granted in the majority of professions. The work of technical assistants was well described in *Staffing our secondary schools* (Secondary Heads Association, July 1980), which identifies the following areas of work in the case of a mathematics department:

—production of teaching materials
—maintenance of files of teaching materials
—financial records
—stationery issue
—cataloguing and indexing
—maintaining rooms
—reprographic work
—maintaining curricular displays
—organizing centrally located books and other resources
—liaison with other ancillary services within the school
—audio-visual aids
—organization and maintenance of equipment
—software collections.

We would expect these 'technicians' to have access to all the general school support services including computing facilities. They would *not* be responsible for teaching pupils.

3.64. The cost of such provision would clearly depend on the size of the department concerned, but the provision of one full-time equivalent 'technician' to every eight full-time equivalent mathematics teachers would appear to be a realistic goal. A smaller department could share a technician either within the school or between schools. It is difficult to provide a detailed costing, although a rough guide per full-time equivalent 'technician' might be £9000–£10 000 p.a. LEAs should be encouraged to develop this provision. It could be linked to such job creation initiatives as those of the MSC and would provide up to 3000 new employment opportunities at a total cost of some £25–30M. The benefits, in terms of increased effectiveness of mathematics teaching and an improved supply of mathematically qualified pupils, would be enormous.

Teaching materials (including high-technology teaching aids)

3.65. The proposal that provision of packages of high-technology learning materials will help to solve the problem of the shortage of mathematics teachers is a superficially appealing one. In the context of the rapid development of computer technology, it might suggest that teachers could be replaced by well-prepared software, videodiscs and the like. However, a sizeable element of caution is required. Computing devices, like textbooks, are merely resources to aid learning. They do not replace teachers, but rather free teachers to be of more direct help to students. Only the student can actually do the learning. In mathematics there is considerable experience of resource-based mathematics teaching (see below), accumulated over a period of 20 years. Although calculators and computers are relatively new, all indications suggest that the same principles apply.

3.66. The advantage of using a wide variety of resources and materials in mathematics teaching is that pupils and teachers both experience the involvement of choice, the attrac-

tiveness of variety, and a sense of mathematics as a disciplined enquiry rather than as a mastery of techniques. Thus a resource-oriented approach to the teaching and learning of mathematics is likely to make both the teaching and learning more attractive, to enhance pupil and teacher involvement, and thus to encourage more people to pursue mathematics for longer.

Resource-based mathematics learning

3.67. Resource-based mathematics learning is a generic term for the organization of learning in mathematics whereby a range of opportunities is offered to pupils enabling them to work at different topics in different ways and at different times. Students may at different times be working on their own, working with another student or working in a group of any size. The activities may include descriptive work, enquiry, understanding processes, making presentations, solving problems, and using and inventing mathematics. Topics and activities become accessible through a range of media, for example books, booklets, cards, sheets, microcomputers, wall-displays, television, written forms (paper, overhead projectors, black and white boards), conversation with teachers with other pupils and with other adults. Associated materials range from stationery, measuring instruments, tools and paper for making shapes and objects (2D and 3D), to complex devices such as calculators and computers. This range of materials offers opportunities for teachers and students to choose from a variety of forms and activities those that are appropriate to the development of the individual.

3.68. The consensus among teachers seems to be that resource-based learning makes more, not less, demands on the teacher in terms of preparation and variety of activity. The teacher needs to be familiar and confident with:

(i) mathematical thinking processes so that unusual questions that arise can be coped with sensibly and constructively if not actually answered. This requires considerable mathematical confidence;
(ii) an overall sense of the mathematics curriculum, so as not to get lost in the details of particular activities;
(iii) links between materials and ideas that do not clearly belong to a standard topic;
(iv) supporting pupils undertaking different tasks;
(v) assessment of what may be learnt, in terms of both content and process, in new ways;
(vi) management of sophisticated hardware, often in inadequately equipped classroom conditions;
(vii) management of software;
(viii) management of student and teacher time;
(ix) management of student attention, in particular, helping them to be aware of general principles rather than just the details of an activity.

3.69. More importantly the use of such resources requires teachers to adopt a role that is very different from the traditional model. For these resources to be used well, control of what is being learnt is passed to the pupil. Teachers need greater skills of knowing how to encourage pupils to suggest questions or problems that can be investigated. Some pupils may ask questions that cannot be anticipated, so the teacher will need greater knowledge of what might be possible, stemming from many different starting points. The art of knowing how and when to intervene has to be acquired. All these aspects of the teacher's role require a considerable degree of confidence, both mathematically and pedagogically.

3.70. History shows that successful curriculum development projects are those in which teachers themselves have taken the initiative. It is not enough only to produce materials; resources ranging from Cuisenaire rods to computer disks, and from dotty paper to workcard schemes, remain unused on many shelves. By contrast, curriculum development that has been *initiated* by teachers has been of immense value in the hands of appropriately skilled experienced teachers. Teacher-initiated and teacher-oriented development of materials employing new technology should be encouraged and appropriately supported. One domain that requires more than the meagre resources available to individual teachers is

mathematical animations. Strong beginnings were made in the 1960s on 8 mm film loops, and more recently by the Open University on video. New technology makes these cheaper, easier to use and more accessible. Many mathematical ideas are dynamic in essence, for example, functions and transformations, families of curves such as probability distributions, and families of geometrical loci. Most mathematical ideas concern a generality of some sort. One powerful way to experience the range and scope of generality is through animation of generic cases. Good examples can be found in Nicolet Geometry films, Take Half (Smile program), some OU video animations, and in a range of software. Videos of complex computer animations should be made and distributed both for A-level and for GCSE use. The Mathematical Association of America is trying to raise funds to embark on a similar project for American undergraduates.

Departmental facilities

3.71. The Cockcroft Report (HMSO 1982) states, 'We are in no doubt that in secondary schools mathematics should be taught in suitably equipped specialist rooms and that their provision makes it easier for good practice to develop ... it is preferable for certain rooms to be designated for mathematics and for these to be grouped together.' The provision of such a professional environment, suited to the demands of modern curricular developments and the variety of learning styles, is a crucial factor in promoting collaborative work by the mathematics department.

3.72. Many secondary schools now have a set of rooms devoted to mathematics teaching. A grouped suite of rooms is necessary, so that all the mathematics teaching in a school can happen in the same place (similar to the 'science block'). Such a suite should encompass the following:

(i) A non-teaching room where the mathematics staff can meet and work together.
(ii) A resources centre with an adequate supply of textbooks and other learning materials, equipment for use in lessons, materials and facilities for making school-based curricular items, access to reprographic facilities reference and resource books for teachers, appropriate storage facilities for this equipment and for pupils' work, and the use of video equipment.
(iii) Each classroom should have at least one calculator per two pupils; at least two microcomputers; suitable furniture; display boards for use by pupils.
(iv) A departmental non-teaching assistant responsible for the maintenance of the resources in the suite.
(v) Capital investment and sufficient recurrent funding to maintain and replenish the resources.

3.73. A survey of existing facilites for mathematics in schools is now urgent. It should examine, by visits to schools, what facilites are already available, how they are being used, their impact on teaching styles, and whether LEAs have a consistent policy towards the provision of mathematics suites. The survey should encourage schools to elaborate, where necessary, on why their arrangements for mathematics teaching are unsatisfactory, on other priorities in the school, and on the cross-disciplinary effects of making changes in favour of mathematics suites.

3.74. The design of such facilities will depend on whether new buildings are provided for schools or whether, as is more likely, existing buildings are adapted. Teachers should be actively involved in defining specifications for the mathematics suite and coordinating the requirements for teaching resources within the constraints of the school building. It would be helpful if the DES could prepare an illustrated pamphlet depicting the types of mathematics suites that can be achieved in various circumstances.

Fostering the use of mathematical resources

3.75.

(i) *Availability*. Mathematical resources must be readily to hand. This might mean provision in each classroom, or possibly shared provision in a mathematical suite of rooms. Teachers should have access to a microcomputer that is not in regular

classroom use, for their own development work. There is a skeleton of non-computer resources, and a growing quantity of software, that must also be to hand, and with which teachers need to be familiar and confident so that they integrate its use into their teaching.

(ii) *Motivation.* Teachers need to be convinced that resources can enhance teaching/learning in some way before they can be expected to make the effort to become familiar with their use or to integrate them into their teaching. This could entail, for example, seeing other teachers making use of the resource, either directly or on video tape, or in discussion with other teachers.

(iii) *Awareness.* Not all teachers have the vision to see how any particular resource might be used. There is a need for workshops in which teachers can get involved in using the resource as their pupils might be expected to do, and so get a feel for what is involved. Opportunities for teachers to talk through their use of resources, and consequent questions and ideas, with others should be provided.

(iv) *Support.* This might be provided in a number of ways:
   (*a*) from an advisory teacher who is familiar with the resource and who will work alongside the teacher in the classroom in initial exploratory work with pupils;
   (*b*) from the opportunity to work in the classroom with a more experienced colleague who is using the resource;
   (*c*) by technical assistance where appropriate, e.g. with microcomputers, to cope with machine operation or failure, or with the preparation of materials;
   (*d*) from easy-to-follow instructions on the use of hardware, to allow people to get started without being inhibited by initial frustrations.

(v) *Time.* This is the most essential requirement for new ideas to be assimilated and incorporated. Time must be provided for motivation and for raising awareness, also for thinking, planning and evaluation. It is particularly important at the early stages of using any new equipment or course programme. Where possible this provision should be during school hours. However, in situations where cover is unavailable, teachers could be paid for their time spent outside school hours in attending workshops, etc. Consideration should be given to paying teachers to engage in professional development in their own time. This would cost no more than providing cover, would indicate to teachers that they were valued, and could ease both the strain on pupils of being looked after by supply teachers and also the strain on local education authorities to find cover.

Implications for, and impact on, teaching styles

3.76. A teaching resource, be it software, textbook, video, worksheet or physical apparatus, cannot, by itself, solve any problems or change teaching styles. Resources that exist may or may not be used. Different types of resource support the adoption of particular types of classroom interaction. Thus, a videotape or real-time computer animation can be used to explore the struggle to express what has been seen and to account for or explain it, and so can stimulate discussion.

3.77. Computer software that is language-like (in the sense of a resource to support exploration of a mathematical idea) can be stimulating. It enables the teacher to adopt a collaborative role, because teacher and students are both facing the same problem. Mathematical adventure games can prompt a teacher to let go of tight control, and thereby discover that the pupils can engage in productive work unattended.

3.78. When pupils come to the end of a period of focused work it is desirable that they integrate what they have discovered or experienced with other classroom activity to enhance their learning. But a common experience is that when the machine is 'turned off' pupils have a moment of blankness like a gap between worlds, before re-entering the ordinary world. After that hiatus, only fragments remain in memory. Teachers can make use of this phenomenon, by stimulating pupils to try to construct a coherent account of what the program/workcard was about. Indeed, helping students to make coherent sense, as distinct

from simply 'conveying information' in 'delivering a curriculum', is an important part of teaching. Teachers should have some flexibility and choice in how a resource is be used, so that they are more likely to integrate it into their teaching. This parallels the observation that pupils who are involved in choosing or formulating their tasks are more likely to become engaged and involved.

Resources and examinations

3.79. Changes by 1991 in GCSE teaching, to accommodate investigational work, will create an expectation in pupils for a similar style of teaching in subsequent courses. This expectation will be reinforced in those pupils who intend to go on to courses in higher education, for example engineering and, increasingly, mathematics, where project work plays an important role. This may be expected to lead to significant changes in A-level teaching and assessment that have serious resource implications. For example, many investigations are likely to involve the use of microcomputers.

3.80. In applying mathematics, the use of resources such as videos and software will be important in developing pupils' elementary modelling skills. At least one project involving university and school teachers is already experimenting to this end. It is hoped that examinations will take account of such developments. Coventry Polytechnic already conducts some examinations in the microcomputer laboratory for courses based on microcomputer use.

3.81. Another change that should be anticipated by the A-level examination boards is the impact of the new generation of hand calculators with facilities for curve sketching, differentiation, integration and algebraic operations such as partial fractions. The ready availability of these will mean that many of the present A-level questions will need to be recast into different forms.

4. CONCLUSIONS AND RECOMMENDATIONS

4.01. Alternative strategies to provide for the teaching of mathematics have been explored in the previous section. There are, no doubt, other no less significant strategies that could be offered. There is no one answer to the problem and all the suggestions will require further thought. But what is clear is that there are many dynamic factors, each of which influences the supply of mathematics teachers and the success of mathematics teaching. Three tasks must be achieved simultaneously if a disaster in the 1990s is to be avoided: more qualified graduates must be persuaded to enter teaching as a rewarding career; more pupils must be encouraged to study mathematics into sixth-form and higher or further education; and means must be found to use more effectively the expertise of those mathematics teachers we have. It is vital that steps are taken to optimize these factors and to work in a positive way to alleviate the problem areas. To this end we have drawn up a number of conclusions and possible courses of action applicable at different levels throughout the educational system. The conclusions in this section have been constructed to address directly the diverse groups that are influential in improving mathematics teaching. Each group has its own set of self-standing conclusions, which look at the proposals uniquely relevant to that group. Each set of conclusions is followed by suggested courses of action. Those aimed at classroom teachers, heads of mathematics departments, headteachers, LEA mathematics advisers and teacher educators are in the form of a checklist. Recipients in these areas are invited to check their existing practice against the ideas listed and consider whether any useful changes could be made. Obviously, some people will have considered the issues more than others, but we hope that the checklists will provide something helpful for everyone. The actions aimed at the SEC and examination groups, LEAs, DES, HE admissions tutors, HE mathematics departments and the professional mathematical associations are, by necessity, written in the the form of formal recommendations. It is, of course, to be hoped that all readers will also take the time to consider the full set of conclusions, checklists and recommendations in detail, and thus gain an overall appreciation of the scale of the proposals at all levels.

Classroom teachers

4.02. The discussion in section 3 suggests that the organization of teaching methods and of mathematics departments in schools affects the way in which pupils perceive mathematics, their performance in mathematics, and their ultimate desire to continue with the subject beyond the compulsory period. A number of discontinuities in the education process, in particular at the transition between primary and secondary school, do nothing to enhance mathematics education. Many pupils are more successful when the problems and tasks used in mathematics lessons allow them to respond at a variety of levels. Some pupils seriously underachieve in mathematics because of their teachers' low expectations of their abilities and their own feelings of failure. In particular, many girls under-participate and underachieve in mathematics. Teaching materials that are unbiased according to gender, and teaching styles that encourage cooperative work and problem solving, encourage girls to perform better. Furthermore, resource-based teaching allows all pupils, as well as teachers, to experience choice and variety and to sense mathematics as a disciplined enquiry. Mathematics is too often perceived by pupils as a 'dehumanized' subject in the school curriculum, taught in too narrow a context with little reference to its historical and cultural origins. Considerable time and effort is required to incorporate new ideas into classroom teaching, but the pay-off is worthwhile. Too many pupils leave school with the impression that mathematics is a dull subject and that teaching it would not be a rewarding experience.

Checklist for classroom teachers

4.03.

(i) Are there any serious discontinuities in the teaching of mathematics for any of the pupils that you teach (for example at the primary–secondary interface)? If so, are there any ways in which you could help to counter them?

(ii) Do the problems and tasks that you use in mathematics lessons give pupils the opportunity to respond on a variety of levels?
(iii) Do you have equally high expectations of the potential of all mathematics pupils?
(iv) Do you follow the recommendations in the report *Girls and mathematics* (RS–IMA 1986)? Are the teaching materials you use free from bias according to gender? Do you encourage cooperative work in the classroom in the context of a problem-solving and experimental approach to mathematics?
(v) Do you use a variety of resources and materials in mathematics teaching?
(vi) Do you incorporate societal, historical and cultural contexts into the mathematics curriculum, in particular relating mathematics to mathematicians?
(vii) Are you able to find enough time to incorporate new ideas into classroom teaching? If not, is there a way in which your time could be reorganized to better effect?
(viii) Do you encourage pupils to consider mathematics and mathematics teaching as a worthwhile career?

Secondary school heads of mathematics departments

4.04. Many of the suggestions made in the two preceding paragraphs will require the active support and encouragement of the head of department, if the pool of pupils who wish to continue with mathematics beyond age 16 is to be increased. Pupils are adversely affected by discontinuities in the mathematics curriculum. Local primary mathematics coordinators are in a position to liaise over and to ease the transition between primary and secondary schools. Flexibility in the organization of teaching groups in the early secondary years could engender more similarity with the primary school style of teaching. Pupils respond well when teaching methods allow them to participate at a variety of levels. This is particularly pertinent to the success of girls with mathematics; girls show a marked tendency to undervalue their abilities (a view too often reinforced by the expectation of their teachers). A greater emphasis on resource-based mathematics teaching also allows more choice and flexibility in the classroom for pupils and teachers. Mathematics taught in the context of its historical and cultural associations helps to counter the criticism that the subject is perceived as in some sense 'dehumanized'. At sixth-form level a carefully constructed, flexible timetable allows for an A-level mathematics option within a very broad range of A-level subject choices, thereby maximizing the pool of pupils continuing beyond age 16 with mathematics.

4.05. Resources of several kinds will be required in the mathematics department if mathematics teaching in schools is to be developed and improved. First, there is considerable potential for part-time teachers of mathematics to make a contribution. Teachers qualified in two areas can make an invaluable contribution to cross-curricular planning. The best use of part-time teachers in the mathematics department is made if the timetable is drawn up flexibly and creatively to suit their needs, and if departmental meetings are arranged at convenient times for all the department. Non-teaching assistants, of the kind advocated in the Cockcroft Report, will ease the load for the whole department. Second, the facilities available in the mathematics department require careful planning. Cockcroft stressed the need for a mathematics suite of rooms with certain basic facilities in each. Third, teachers need time for new ideas to be incorporated into their teaching methods, and the support of their heads of department. Lastly, teachers are in a position to encourage pupils to consider teaching mathematics as a worthwhile career. FE and HE students are able to gain some experience of actively participating in many areas of employment before they make their final decision about which direction to take. There is no reason why schools should not welcome students in to experience teaching before they finish their higher education courses.

Checklist for secondary heads of mathematics departments

4.06.

(i) Are you able to liaise with your local primary mathematics coordinator as often as necessary?

(ii) Are the teaching groups in your department organized flexibly, and seen to be so by the pupils?

(iii) Do the teachers in your department use a range of problems and tasks in their lessons that give pupils the opportunity to respond on a variety of levels?

(iv) Do you encourage other teachers to have equally high expectations of all pupils' abilities in mathematics?

(v) Do you follow the recommendations in the report *Girls and mathematics* (RS–IMA 1986)?

(vi) Are you aware of the range of resources available for mathematics learning? Are you making effective use of those resources known to you within your department?

(vii) Is mathematics taught through the context of its societal, historical and cultural origins in your department?

(viii) Does the sixth-form timetable allow for an A-level mathematics option within a broad range of A-level subject choices?

(ix) Do you exploit sufficiently the cross-curricular expertise that part-time teachers who are specialist teachers in other subjects can bring to the department?

(x) Is the mathematics department timetable drawn up as creatively and flexibly as possible, taking account of part-time teachers?

(xi) Do you always arrange departmental meetings so that they are convenient for the whole department, including part-timers?

(xii) Have you considered the value of a non-teaching assistant in the department? Have you ever prepared a convincing case for one?

(xiii) Is your department sited in a suite of rooms? If not, have you ever considered how you might move into one?

(xiv) Does each classroom in your department have at least one calculator per two pupils, at least two microcomputers, suitable furniture, and display boards for use by pupils? If not, use the Cockcroft Report and section 3 of this report to argue for these facilities.

(xv) Do you encourage all the mathematics teachers in your department to make full use of the departmental resources that are available?

(xvi) Do you allow your mathematics colleagues sufficient time in their timetables to incorporate new ideas into their classroom teaching? Could you reorganize the timetable to allow more?

(xvii) Do you encourage pupils to consider mathematics teaching as a worthwhile career? Do you encourage other mathematics staff to do this too?

(xviii) Have you considered organizing programmes for FE and HE students to experience what it is like to teach mathematics?

Headteachers

4.07. Heads of mathematics departments will require the active support and encouragement of the headteacher if mathematics teaching is to improve and the numbers of potential mathematics teachers is to increase. The organization of the curriculum, of teaching staff, and of facilities in a school can all affect the quality and scope of mathematics teaching. This is largely the responsibility of the headteacher. A carefully constructed timetable will maximize the number of pupils who wish to continue with mathematics, in particular, at sixth-form level if it allows for an A-level mathematics option within a very broad range of A-level subject choices. Part-time mathematics teachers who are qualified in two areas can enrich a mathematics department by developing cross-curricular provision. Trained mathematics teachers who are not currently working in teaching may not realize the opportunities that exist for them. They may not read the usual journals in which jobs

are advertised. Imaginative advertising, possibly in the local free press or corner shop may be surprisingly effective. Some potential part-timers may be put off by the tendency of schools to cut back on part-time provision in response to falling school rolls. Teachers of subjects other than mathematics who have had successful teaching experience in their original subject, but now have the appropriate motivation and commitment to make career moves into mathematics teaching, are another important potential resource. They need to be identified and, when they have undergone a course of in-service training to teach mathematics, they are an important addition to the mathematics department. Too many of these teachers return after their retraining to continue teaching their former subject, which is a great waste of resources. Good mathematics teaching is becoming increasingly resource-based. Non- teaching assistants are now essential in the mathematics department to organize and maintain equipment, in the same way that the science department relies on technicians. With regard to facilities, resource-based mathematics teaching is best taught in a distinct suite of rooms, as recommended by the Cockcroft Report in 1982. Certain basic resources are essential: at least one calculator per two pupils, two microcomputers in the department, suitable furniture and display boards for pupils' use.

Checklist for headteachers

4.08.

(i) Does the sixth-form timetable in your school enable mathematics A- level to be chosen within a broad range of other A-level options?

(ii) Does your mathematics department benefit from the cross-curricular expertise that a part-time teacher of another subject as well as mathematics can contribute?

(iii) Have you (or your LEA) tapped the local pool of qualified mathematics teachers not currently teaching?

(iv) Have you (or your LEA) considered the potential part-timers that might be raised by imaginative local advertising?

(v) In a climate of falling rolls, when teachers are being redeployed, do you support the same rights for part-time staff as for full-time staff?

(vi) Are there successful teachers in your school who have the motivation and commitment to be retrained to teach mathematics? Have you brought them to the attention of your LEA or mathematics adviser? Do you guarantee that such teachers would be employed to teach mathematics, and not their former subject, after their retraining?

(vii) Do you recognize the benefits of, and encourage, resource-based mathematics teaching?

(viii) Have you considered making provision for non-teaching assistants in the mathematics department?

(ix) Is the mathematics department sited in a suite of rooms? If not, could it be arranged?

(x) Is the mathematics department well resourced? Does it have one calculator per two pupils, two microcomputers, suitable furniture and display boards?

LEA mathematics advisers and advisory teachers

4.09. For any lasting improvement to occur in school mathematics teaching, the headteachers and departmental staff will require positive support from LEA mathematics advisers, who are in a unique position to advise on and encourage good practice, training programmes and the best use of personnel. Resource-based teaching can enhance pupils' learning of mathematics. Heads of department will need the support of mathematics advisers to press for the necessary resources to teach mathematics well. Some teachers lack confidence in using all the available resources in the classroom and need support during initial exploratory work. Resource-based mathematics teaching requires the department to be sited in a distinct suite of adjoining rooms. Mathematics teachers may need help in defining the specifications for such a suite, and in coordinating the requirements of teaching resources within the constraints of the school building. Headteachers should be able to identify good

teachers of other subjects who are sufficiently motivated and committed to wish to retrain to teach mathematics. These teachers will need advice on the career implications of such a move and, in liaison with the headteacher, assurance that they will be employed to teach mathematics after retraining. Interested mathematics teachers also need career advice and information about in-service training provision. In-service training should be a careful balance of school-based provision and external courses. Mathematics teachers working in pairs can benefit from school-based in-service training. Part-time teachers of mathematics are an important asset in a school mathematics department. The mathematics timetable needs to be flexible to accommodate part-timers conveniently, and part-time staff as well as full-timers need to be able to attend departmental meetings. Effective working arrangements can be made when two teachers agree to job share. Information about potential job-sharers needs to be kept centrally in the LEA. Teachers who teach mathematics part-time, and another subject the rest of the time, are a valuable source of cross-curricular expertise.

Checklist for LEA mathematics advisers and advisory teachers

4.10.

(i) Do you encourage teachers to use a variety of resource-based mathematics teaching methods in your area?

(ii) Do you encourage and support heads of mathematics departments in pressing for a well-resourced department (see paragraph 4.06 (xiv))? Do you encourage all classroom teachers to use the resources that are available?

(iii) Do you provide support for teachers using new resources by working alongside them in the classroom in initial exploratory work?

(iv) Do you follow the recommendations in the report *Girls and mathematics* (RS–IMA 1986)?

(v) How many of the mathematics departments in your area are sited in a distinct suite of rooms? Do you involve mathematics teachers in defining the specifications for a suite within the constraints of the school building?

(vi) Do you provide specific career advice and information about in-service training provision to interested mathematics teachers and to other teachers who are considering retraining?

(vii) Does your in-service training strategy ensure a balance between school-based and external provision? Do you make provision for pairs of mathematics teachers to benefit from school-based in-service provision together?

(viii) Do you encourage flexibility in the mathematics timetable to accommodate part-time teachers conveniently?

(ix) Are full-time and part-time staff able to attend departmental meetings?

(x) Do you keep a register of teachers who wish to job-share and advertise that one exists?

(xi) Do you encourage the exploitation of the cross-curricular expertise that some part-time teachers can bring to a mathematics department?

(xii) Does your LEA recognize the need for non-teaching assistants in the mathematics department?

Teacher educators

4.11. Teacher educators have a responsibility to influence wherever possible all the recommendations already outlined above. Teacher training courses aim to make student teachers aware of different teaching styles in the education of new mathematics teachers and through in-service training of existing teachers of mathematics. A number of points need to be emphasized to student teachers. Many pupils are more enthusiastic and receptive when the problems and tasks used allow them to respond at a variety of levels. Many girls and other groups under-participate and underachieve in mathematics because of their teachers' low expectations of their potential. Some teaching resources are biased against certain groups. Mathematics is perceived by some pupils as being difficult and 'dehumanized'. If more people are to be trained to teach mathematics, the minimum entry requirements for initial teacher training courses will need to be widened (see paragraph

4.22 (viii)). Teacher educators are ideally placed to promote mathematics teaching as a worthwhile career for undergraduate students and potential mature entrants. Many mature entrants would find part-time initial teacher training courses convenient. All potential entrants would appreciate 'taster' courses that give an insight into teaching and information about courses and funding.

Checklist for teacher educators

4.12.

(i) Do you encourage student teachers to use a variety of problems and tasks that allow pupils to respond on a variety of levels?

(ii) Do you encourage student teachers to have the highest expectations of *all* pupils in mathematics?

(iii) Do you follow the recommendations in the report *Girls and mathematics* (RS–IMA 1986)?

(iv) Do you press student teachers to reject teaching materials that are biased according to gender or race?

(v) Do you stress the importance of teaching mathematics through its societal, cultural and historical origins?

(vi) Have you put pressure on CATE to modify the minimum entry requirements for initial teacher training courses in mathematics (see paragraph 4.22 (viii))?

(vii) In promoting teaching as a career, do you provide a wide range of facilities for gaining information and advice about teaching as a career?

(viii) Does your institution provide part-time initial teacher training courses? If not, is there scope for such courses?

(ix) Have you considered providing 'taster' courses for potential entrants to initial teacher training courses?

The Secondary Examinations Council (SEC) and Examination Groups

4.13. Many practising teachers are members of the SEC or Examination Group subject committees and are thus in a position to influence their activities. Much of the preceding discussion (section 3) indicates that some features of the traditional examination system for the assessment of mathematics are discouraging some pupils from continuing with mathematics. The greater emphasis on coursework in GCSE mathematics is welcomed. It is important that all learning should be based on earlier preparatory work to which examinations are a culmination; coursework should be integral to the learning process and not a 'bolt-on' extra. Some experimental approaches to assessment such as the SEG modular GCSE, GAIM, and the ATM coursework-based mathematics GCSE show considerable promise in enthusing pupils with a more popular perception of mathematics and its usefulness. It would be interesting to explore the potential of large combined coursework projects being submitted for assessment in more than one subject area. In the 16–18 range, A-level mathematics examinations will inevitably require revision in the light of GCSE; indeed the SEC 18+ committee for mathematics is already considering such a revision. Particular attention will need to be paid to the scope of, and a reduction in, the content of A-level mathematics syllabuses. Courses will need to take more account of the needs of a wider variety of groups, especially girls. More pupils would be able to continue with mathematics after age 16 if A-level syllabuses and assessment were modified to accommodate pupils who gain high grades on GCSE intermediate papers. Double mathematics A-level syllabuses make heavy demands on sixth-form teaching resources and cause difficulties for HE teachers when designing courses for students with different depths of mathematical background. The provision of double mathematics A-level courses in some schools is not widening access for all pupils to HE. Alternative routes into HE to the traditional A-level course in mathematics should be promoted to widen access to HE, for example the wider use of BTEC as an acceptable alternative prerequisite for HE mathematics courses. This will require close liaison between the appropriate national bodies.

Recommendations to the SEC and Examination Groups

4.14.

(i) Develop the welcome emphasis on coursework in GCSE assessment as an *integral* part of the learning process and not as a 'bolt-on' extra.

(ii) Provide the possibility for large combined coursework projects to be submitted for assessment in more than one GCSE subject area.

(iii) In reviewing A-level mathematics courses in light of GCSE, pay particular attention to the scope of, and a reduction in, the content of mathematics syllabuses.

(iv) Make A-level mathematics courses more flexible and more attractive to a wider variety of groups. Follow the recommendations in the report *Girls and mathematics* (RS–IMA 1986).

(v) Modify A-level syllabuses and their assessment so that those gaining high grades on GCSE intermediate papers can attempt A-level courses.

(vi) Consider the abolition of double mathematics A-level syllabuses.

(vii) Establish close liaison with the National Council for Vocational Qualifications (NCVQ) to promote and to ease alternative qualifications to A-level for HE courses.

Local Education Authorities (LEAs)

4.15. Most of the ideas and recommendations above require the positive support of the LEA if mathematics is to be taught well in schools to the greatest possible number of pupils. School mathematics is rapidly developing and the pressure for change, from both teachers and 'users' is strong. Accordingly, a flexible approach to curriculum development in mathematics can help to facilitate its teaching. Mathematics teaching is becoming increasingly resource based. Much of a mathematics teacher's time is lost to pupils in preparation and repair of teaching resources. The provision of a non-teaching assistant to manage resources in the mathematics department was recommended in the Cockcroft Report. This provision is still not available in most schools. The design of school buildings needs to be carefully planned so that the mathematics department can be sited in an appropriately furnished suite of rooms. Part-time teachers of mathematics are an important resource for schools to tap. There is a considerable number of trained mathematics teachers who are not currently teaching and may be unaware that they are needed in schools. These teachers will not be reached without imaginative advertising. Some of them might prefer to job-share if appropriate arrangements could be made. Unfortunately, a number of factors may be deterring potential part-time teachers from offering their services to schools. Part-timers often do not have the same job security as full-timers. This is particularly important in the current climate of falling school rolls. Returning teachers contemplating working part-time need well-designed refresher courses. Once in school it is reasonable that these teachers are paid a salary with the same prospects for promotion as other staff (some are employed on a fixed scale 1 salary). Former teachers of other subjects who have left teaching are not paid a salary while they retrain to teach mathematics. This does not encourage such teachers to come forward. The arrangements for funding students on initial teacher training courses need examination. Student grants are still subjected to a parental means test. This compares unfavourably with other postgraduate courses. Mature students grants are low and this must discourage people from training to teach 'late'. Mature students are not fully rewarded, in terms of salary increments, for their previous relevant experience. Students who take approved part-time advanced mathematics courses before initial teacher training courses do not receive full financial support. None of these factors helps to increase the numbers entering teacher training. The overall provision of in-service education and training in mathematics needs to be carefully planned. A balance needs to be struck between school-based and institution-based INSET, and proper account of long-term secondments needs to be taken in the funding arrangements.

Recommendations to LEAs

4.16.

(i) Approach curriculum development in mathematics flexibly to allow for rapid change.

(ii) Given that mathematics teaching is becoming increasingly resource based, make provision for each school mathematics department to have a non-teaching assistant (similar in kind to those in science departments). Press central government for funds.

(iii) Design new school buildings such that the mathematics department can be sited in a suite of rooms. It may be possible for existing schools to be reorganized.

(iv) Advertise imaginatively for part-time work teaching mathematics, for example in local papers or corner shops.

(v) Keep a register of teachers in the Authority who wish to job-share; advertise its existence.

(vi) Ensure that part-time mathematics teachers have the same job security as their full-time colleagues.

(vii) Send returning teachers, contemplating taking a part-time job teaching mathematics, on refresher courses.

(viii) Provide for part-time mathematics teachers the same relative salary and prospects for promotion as full-timers.

(ix) Pay former teachers of other subjects who have left teaching, but wish to return, a basic teachers' salary while they retrain.

(x) Remove the parental means test on student grants for initial teacher training courses covering one or two years, and also the last year of four-year courses.

(xi) Make a mature student's grant for an initial teacher training course in mathematics the equivalent to the first-year salary in teaching.

(xii) Award mature entrants to mathematics teaching appropriate salary increments to reflect other relevant experience.

(xiii) Provide full financial support for students who take approved part-time advanced mathematics courses before embarking on initial teacher training.

(xiv) Design broad-based in-service training strategies in mathematics when determining funding arrangements, take account of the need for long-term secondment in some instances.

(xv) Strike a balance between school-based and institution-based in-service training.

Higher education admissions tutors

4.17. For demographic reasons the pool of potential HE students is shrinking, at least into the 1990s. The shortage of mathematics teachers in schools will further exacerbate the shortfall in potential mathematics undergraduates. Accordingly, there is likely to be increasing competition for suitable students between HE institutions. It is no longer appropriate for students to be selected solely on the basis of A-level grades. The 16–18 curriculum has changed considerably over recent years and is likely to change further in response to GCSE. Students now take a variety of traditional courses that prepare them for A-level and AS-level examinations, as well as vocational qualifications such as BTEC. Mature students may not have suitable A-level qualifications, but appropriately designed courses could provide them with an alternative route into existing HE mathematics courses.

Recommendations to HE admissions tutors

4.18.

(i) Make admissions policy for HE mathematics courses flexible to take account of the educational background of all potential undergraduates (not just students with A-levels).

(ii) Accept a BTEC qualification as an acceptable prerequisite for HE mathematics courses.

(iii) Pay careful attention to 'access' courses that allow alternative means of entry into existing HE mathematics courses for those without suitable qualifications.

HE departments of mathematics

4.19. GCSE mathematics teaching has an increased emphasis on inquiry, investigation, discussion, practical work, extended tasks and cooperative group work. Teaching methods are becoming increasingly resource based. It is inevitable that GCSE will have a 'knock-on' effect on the content and assessment of the 16–18 curriculum, which in turn will have implications for HE mathematics courses. The emphasis in GCSE on skills and processes means that there has been a welcome reduction in the content of 16+ mathematics courses. In future pupils will achieve a deeper understanding of less content. Some account of this reduction in content will have to be made in 16–18 courses and at 18+. Many graduate mathematicians who go into industry, commerce or government never use any mathematics from their third-year degree work; indeed some never use any from their second-year work. A reduction in the content of mathematics degree courses would not be detrimental to the needs of the majority of graduates. It would also reduce the pressure on content on A-level mathematics. Many pupils who have the aptitude to embark on and complete a mathematics degree fail to do so. Few students transfer into mathematics courses from other HE courses, but many transfer out. The HE atmosphere appears hostile to some groups of people and some teachers advise students to opt for 'easier', more attractive degree courses. These impressions need to be countered if there are to be enough students to fill HE mathematics courses. Teaching in schools also needs to be promoted as a worthwhile and rewarding career. Lecturers in HE departments of mathematics are well placed to promote and to talk to second and third year degree students of mathematics and other numerate subjects about school mathematics teaching.

Recommendations to HE departments of mathematics

4.20.

(i) Design HE mathematics courses flexibly to take account of the emphasis in GCSE courses on skills, processes and investigative work, and of the increased use of resource-based teaching methods.

(ii) Radically re-assess and reduce the content of HE mathematics courses.

(iii) Make HE mathematics courses more attractive to a wider group of students. Courses should not be perceived as difficult or hostile by students.

(iv) Design courses to facilitate transfer from other numerate undergraduate courses into mathematics, at least throughout the first year.

(v) Promote school mathematics teaching to second and third year students of numerate subjects. Make information and advice on teaching as a career readily available.

Department of Education and Science

4.21. The principles behind GCSE demand a review of the post-16 mathematics curriculum and assessment. The Higginson Committee is reviewing the role of A-level examinations and it is clear that mathematics A-level syllabuses will have to be radically different in style and reduced in content if GCSE pupils are to be able to benefit from them. HE mathematics courses will also have to be reviewed (see paragraphs 4.19–4.20) and HE admissions policies must become more flexible. Mathematics teaching in schools is undergoing rapid change, becoming increasingly resource based. Accordingly, development of the mathematics curriculum needs to be increasingly flexible. The Cockcroft Report recommended the provision of non-teaching assistants in mathematics departments, and that the department should be sited in a suitably equipped suite of rooms. Each mathematics classroom should have at least one calculator per two pupils, two microcomputers, suitable furniture and display boards for use by pupils. Microcomputers are constantly developing and some models in schools have already been superseded. The national picture of existing departmental facilities for mathematics is unclear and central guidelines would be helpful for LEAs and headteachers. It is most important that initial teacher training

courses are well advertised to students. For this reason the new teaching as a career unit at DES is welcome; much still needs to be done. CATE guidelines on the entry qualifications for and the content of initial teacher training courses in mathematics do not provide sufficiently wide access. A number of organizations (the MSC, OU, NAB and UGC) have recently been involved with resourcing initial teacher training courses. Such initiatives must be effectively coordinated. A number of recommendations have been made in this report (see paragraph 4.16) to LEAs with regard to grants and salaries for students, on initial teacher training courses, namely improving the grant for all students, removing the parental means test, paying mature students first-year teaching salaries, and supporting students who are taking part-time mathematics courses before teacher training. It would be reasonable for mature students beginning their first teaching job to receive salary increments for previous relevant experience, and for former teachers of other subjects, who wish to return to teaching retrained as mathematics teachers, to be paid a basic teaching salary to do so. Such recommendations have implications when allocating resources to LEAs. The funding of the GRIST initiative also needs to be re-examined to ensure that it is enabling LEAs to fund long-term teacher secondments to cover those on retraining courses. Lastly, and most importantly of all, the number of good quality mathematics teachers is unlikely to increase appreciably until the salaries are at least close to what a good mathematics graduate can earn elsewhere.

Recommendations to the DES

4.22.

(i) Pay mathematics teachers salaries as closely related as possible to what a good mathematics graduate can earn elsewhere.

(ii) Review mathematics A-level syllabuses so that they complement the different emphasis in style, and reduction in content, of GCSE courses.

(iii) Centrally support and promote resource-based mathematics teaching.

(iv) Make resources available to implement the Cockcroft recommendations, in particular so that mathematics courses can be taught in a suite of suitably equipped rooms (see paragraph 4.21), serviced by a non-teaching assistant.

(v) Distribute an illustrated pamphlet to all schools demonstrating the types of mathematics suites that can be achieved in schools.

(vi) Initiate a central survey of existing departmental facilities for school mathematics that could be used to draw up suitable guidelines for LEAs and headteachers.

(vii) Widely advertise and promote initial teacher training courses in mathematics.

(viii) Modify CATE guidelines to provide wider access to teacher training, as follows:
- (*a*) four-year BEd: GCSE mathematics grade A, B or C and 2 A-level passes (not necessarily including mathematics);
- (*b*) two-year BEd: BTEC higher or overseas qualification in a numerate area not currently recognized as U.K. degree equivalent;
- (*c*) two-year PGCE: GCSE mathematics grade A, B, or C and a degree (or equivalent) in non-numerate subject;
- (*d*) one-year PGCE: degree (or equivalent) in numerate area for first *and* second method courses; and
- (*e*) all courses in mathematics no longer required to provide the equivalent of two years of an honours degree in mathematics.

(ix) Coordinate initiatives by different organizations (e.g. MSC, OU, NAB and UGC) to resource initial teacher training courses.

(x) Make resources available so that LEAs can re-equip school mathematics departments with microcomputers at reasonable intervals in line with technological development.

(xi) Fund LEAs sufficiently to provide for the following:
- (*a*) improve the grant for all students on initial teacher training courses;
- (*b*) remove the parental means test on initial teacher training courses.

(*c*) pay first-year teaching salaries to mature students on initial teacher training courses;
(*d*) support students taking part-time mathematics courses before initial teacher training courses;
(*e*) pay appropriate salary increments to mature students beginning in teaching according to their previous relevant experience;
(*f*) pay a first-year teaching salary to former teachers of other subjects who wish to retrain in mathematics and return to teaching.

(xii) Review GRIST funding to ensure that LEAs are able to fund the secondment for teachers on long-term retraining courses.

(xiii) Fund HE mathematics departments adequately to deal with the consequences of more flexible admissions policies.

(xiv) Continue to provide funding for advisory teachers of mathematics under the Education Support Grant (ESG).

(xv) Continue to provide funding for the professional mathematical associations to provide INSET courses, to produce teaching materials and to run conferences.

Professional mathematical associations

4.23. All of the professional mathematical associations will be concerned about the shortage of good quality mathematics teachers and the implications this has for replenishing and increasing the pool of mathematicians. Mathematics has a poor public image. It is perceived as a difficult and somehow 'dehumanized' subject. Girls do not participate in or achieve at mathematics as well as boys. The Joint Mathematical Council has been considering the public image of mathematics recently, but there is still much to be done to make mathematics appear more attractive to a wider group of students. The professional associations provide valuable in-service training provision for mathematics teachers, in particular through working groups, courses and conferences. It is hoped that even within the present climate of tight resources, the associations will be able to keep up their in-service work for teachers. There is now a considerable variety of teaching schemes and teaching resources available to mathematics teachers. Information about these schemes and resources needs coordinating so that teachers are fully aware of what is available to them.

Recommendations to professional mathematical associations

4.24.

(i) Strengthen and promote the public image of mathematics whenever possible.

(ii) Support and promote initiatives that positively encourage girls as well as boys to participate and achieve fully in mathematics.

(iii) Continue to support in-service training for teachers provided by the associations through working groups, courses and conferences.

(iv) Establish a watchdog committee to publish annually a teachers' guide to major teaching schemes and resources available in mathematics.

APPENDIX A

Programme and list of particpants at a workshop held at Sheffield Polytechnic, 13–15 March 1987

Programme

The workshop aimed to explore ways of maintaining the teaching of mathematics in schools, given the growing shortfall in the numbers of qualified mathematics teachers. The event was organized by an *ad hoc* group of the RS–IMA Mathematical Education Joint Committee to consider and report on the shortage of teachers.

The workshop considered changes in curricular style and content to make mathematics more accessible, especially to girls; increasing the use of computer-learning; adopting a more algorithmic approach to mathematics teaching; and increasing the effectiveness of teachers by the use of more resources in the mathematics classroom.

For each session three concurrent discussion groups considered a number of areas.

Session 1: Options

(*a*) *Changes in the approach to content of mathematical curricula*
Chairman: Mr N.L. Biggs
Recorder: Mr E.R. Ashley

(*b*) *Changes in teaching styles*
Chairman: Mr D.W. Lingard
Recorder: Mr H. Neill

(*c*) *Changes in organization within schools and between phases*
Chairman: Professor R.L.E. Schwarzenberger
Recorder: Dr Daphne Kerslake

Session 2: Implications

(*d*) *Provision of facilities and the role of technical and teaching assistants*
Chairman: Dr D. Woodrow
Recorder: Dr A.J. Bishop

(*e*) *Provision of extra teaching materials (including high-tech. proposals)*
Chairman: Mrs A. Straker
Recorder: Dr J.H. Mason

(*f*) *Provision and requirements for initial and in-service training*
Chairman: Dr W.S. Wynne-Willson
Recorder: Dr Christine Shiu

Session 3: Implementation

Chairman: Professor D.G. Crighton
Recorder: Ms J.A. Nelson

Each recorder reported on the working group discussions. A general discussion followed on the implementation of the issues raised.

Participants

Mr E.R. Ashley
Mr N.L. Biggs
Dr A.J. Bishop
Mr W.M. Brookes
Professor W.D. Collins
Professor D.G. Crighton
Mr P. Dines
Mr J.W. Hersee
Professor D.J.G. James
Ms B. Jaworski
Professor D.G. Johnson
Dr D. Kerslake
Dr I. Huntley
Mr D.W. Lingard
Dr J.H. Mason
Mr H. Neill

Professor C.A. Rogers
Mr D. Roseveare
Dr K.B.H. Ruthven
Professor R.L.E. Schwarzenberger
Dr C. Shiu
Mr J. Slater
Ms T. Smart
Mrs A. Straker
Mr P. Swift
Mr R.S. Taylor
Ms A. Walsh
Dr D. Woodrow
Dr W.S. Wynne-Willson

Workshop organizer: Ms J.A. Nelson

APPENDIX B

Questionnaire to investigate student teachers' perceptions of the teaching profession

1. Age: ; Sex: M/F; Nationality: ; Institution:

2. What type of course are you on? PGCE/BEd/other (please specify)

3. Is mathematics your only teaching subject? YES/NO. If NO, what subjects can you teach (in your order of preference) including mathematics?

If you intend to enter teaching from September 1986 answer questions 4–7.

4. Do you intend teaching in a maintained school/independent school/other? In this country/abroad? Age range: primary/middle/secondary/other (please specify)

5. What are the main reasons for your choice of school?

6. Have you a job yet?

7. How many years do you intend staying in teaching?

Please continue from question 13.

If you do not intend to enter teaching for September 1986 answer questions 8–12.

8. Which of the following are your main reasons for not intending to teach (number, from 1, as many as you wish in your order of importance):

Pay levels too low	Little job satisfaction
Poor work conditions in school	Too time consuming
Low status of teaching	Little career prospects
Too hard a job	Others (please specify)

9. What *do* you intend doing next year?

10. Why did you choose to do this?

11. Do you intend teaching in the foreseeable future? YES/NO

12. If YES, why delay entering teaching?

Please continue from question 13.

All respondents to answer questions 13 and 14

13. What would *you* do to increase the number of students entering mathematics teacher training courses?

14. What would *you* do to increase the number of student teachers entering mathematics teaching?

APPENDIX C

Questionnaire to investigate experienced teachers' perceptions of the teaching profession

Age: Male/Female: Position/Scale:

Qualifications: Number of years teaching:

Type/size of current school: Number of staff in maths department:

Do you anticipate always teaching? YES/NO

Do you hope early retirement will be available? YES/NO

Considering 1. Pay levels
2. Working Conditions
3. Status of the job
4. Difficulties of the job
5. Job satisfaction
6. The commitment required

(i) Which are the most likely reason(s) for staying in the job?

(ii) Which would most likely cause you to leave the profession?

Have any members of the maths department left the profession recently? YES/NO

If so, why do you think they left?

What would *you* do to increase the number of students entering mathematics teacher training courses?

What would *you* do to increase the number of student teachers entering mathematics teaching?

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