Mathematics Enhancement Programme (MEP)

The First Three Years

by

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Abstract

This paper outlines the problems and effects of implementing the findings of a 3-year international comparative study on mathematical progress, starting at Y10, then Year 7 in secondary schools in England and Wales, and later extending to partner primary schools, with the ultimate aim of creating a highly effective, integrated Y1–11 course in school mathematics.

1. Introduction

As in the United States, mathematics teaching in the United Kingdom has been the subject of controversy over the past decade, particularly in the national press where there has been much criticism of the reforms which have taken place during the last 40 years.

In the 1960s, mathematics teaching, especially in primary schools, moved away from the traditional 'chalk and talk' approach after the publication of the *Plowden Report* (1) which encouraged individualised learning and exhorted teachers not to make pupils feel failures. At the same time, 'Modern' mathematics was introduced into the curriculum, emphasising the structure of mathematics through new as well as traditional topics (2).

The reforms of the 1980s followed the publication in 1982 of the influential Cockcroft report, *Mathematics Counts* (3), which called for a less didactic style of teaching mathematics and encouraged the use of:

- investigations
- problem solving
- applications
- discussion

and also a bottom-up approach to syllabus construction rather than the usual top-down. Advisory teachers were appointed to help implement these changes and assessment frameworks were altered. Coursework now played a significant role in 16+ national examinations, which were revised as the General Certificate of Education (GCSE), with three tiers of entry in order that all pupils could achieve some success.

Although there had been continual criticism of school mathematics in the UK throughout the last century, never was it as severe as in the 1990s, which was disappointing because the Cockcroft report had seemingly united the mathematics teaching profession – academics, teachers and administrators – in working together to implement the reforms. Even academic societies voiced their despair, with the London Mathematical Society's report (4) calling for yet more reforms and arguing that the school mathematics syllabus had been dumbed down so

much that little real algebra and geometry now existed in the compulsory national curriculum for pupils aged 5–16.

Much of the rhetoric at that time was based on anecdotal evidence rather than rigorous research, so it seemed opportune to obtain empirical evidence in order to shed light on whether standards in school mathematics really had fallen in the UK compared with those in other countries and if so, how serious was the problem and what could be done to rectify it.

2. The Kassel Project

The *Centre for Innovation in Mathematics Teaching* (CIMT) at the University of Exeter was already collaborating with colleagues at Kassel University in Germany with the aim of comparing and contrasting how real-life applications were being taught in secondary school classrooms. The study was broadened to monitor the progress made by secondary school pupils in core mathematical topics over the last three years of compulsory education, with the aim of determining, using tests, questionnaires, observations and interviews, the key factors which gave rise to successful progress.

After a year, a number of other countries joined the original participants (England, Scotland and Germany) and this is the final list of participants:

Australia	Brazil	Czech Republic	England	Estonia
Finland	Germany	Greece	Holland	Hungary
Japan	Norway	Poland	Russia	Scotland
Singapore	Thailand	Ukraine	USA.	

It should be noted that not all the countries completed all the testing and not all the samples were representative. The test regime for the majority of countries is summarised below.

		Sept. 93	**Sept. 94**	**Sept. 95**	**May 96**
	Potential Test	✔	×	×	×
Topic Tests	*Number*	✔	✔	✔	✔
	Algebra	✔	✔	✔	✔
	Shape and Space	✔	✔	✔	✔
	Handling Data	✔	✔	✔	×
	Age of pupils (yrs)	13+	14+	15+	16

The methodology (see (5)) was to use the test data to compute a double value-added measure based on the *Potential Test* (which measured pupils' natural mathematical ability and was relatively content free) and the *Topic Tests* (which measured attainment). Essentially, we grouped pupils of similar ability and attainment at the start of the project and determined the value-added score of each pupil over a year, with reference to the average progress made during that year by their particular ability group.

After a year, we had value-added measures for all pupils who had taken both rounds of tests and hence an average value for each class, teacher and school. (Value-added measures were only computed within a country and not on an international basis.) These measures indicated where further in-depth study should be undertaken. We also used questionnaires for each country, school, teacher, class and pupil to obtain general information about the learning environment.

However, the most interesting phase of the project was the observation of teaching and the interviews with teachers and selected pupils. We concentrated on classes and pupils with high or low value-added measures within schools where the majority of classes were either very positive or very negative, although even schools with mixed results were of interest. Often, there were obvious explanations for some of the extreme data, for example:

- high turnover of staff (with sudden departures)
- long term illness or frequent absenteeism of staff
- high truancy rate
- pupil illness or movement
- pupils receiving private tuition

but in the majority of cases, the style of teaching did appear to be a key factor.

In England and Scotland, the test data, lesson observations, questionnaires and interviews indicated that enhanced progress was associated with

- stability of staff
- whole class teaching
- clear, concise explanations
- effective monitoring of individual work
- mistakes used as teaching points
- prompt start to lessons, with good pace throughout and very little time wasted
- homework set, marked and returned quickly, with written comments
- misconceptions dealt with at the time
- pupils kept on task, responding well to questions
- positive classroom ethos
- variety of activities;

whereas poor progress was associated with

- individualised learning
- pupils sitting around tables with little or no direct teaching
- teachers sitting at their desks, only responding to pupils who asked for help
- very slow start to the lesson and a great deal of time wasted during it
- pupils and teachers ill prepared
- majority of pupils off task for most of the lesson
- teacher unaware of how much work was done by pupils during the lesson
- noisy, disruptive, confrontational classrooms
- severe discipline problems
- teacher spending significant amounts of time helping one or two pupils
- little or no variety in activities.

If the project had been restricted to the UK, we would still have been able to make a number of useful recommendations but the participation of other countries raised the study to another plane and radically affected our eventual recommendations for mathematics teaching in the UK.

Each participating country had a coordinator appointed but, as the lead institution, staff from CIMT were fortunate to observe teaching not only in schools at both ends of the scale in the UK but also in countries at the extreme ends of the data. We were surprised and excited by much of what we observed in those countries which achieved significantly higher progress and attainment during the years of the study than either England or Scotland.

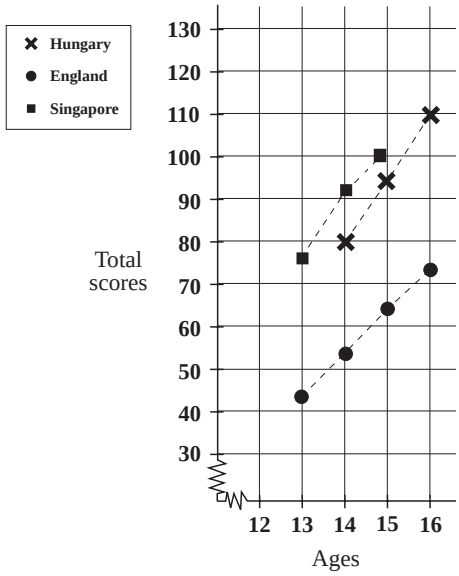

Fig. 1: Progress on Topic Tests made by representative samples of pupils

Fig. 1 compares the attainment and progress of representative samples of pupils in England with the two highest performing countries in the project, Singapore and Hungary.

Note that:

1) attainment is based on the total score on three of the **Topic Tests**, *Number*, *Algebra* and *Shape and Space*[1] (each had 50 marks available, so the total score possible was 150 marks);

2) the *Handling Data Test* is not included as its content was not part of the official curriculum in either Hungary[2] or Singapore.

We will look now in more detail at what we observed in these two highest performing countries, although it should be noted that many other countries close to Hungary in progress and attainment also emphasised and reinforced the points that we now make.

a) SINGAPORE

As can be seen from the earlier graph, pupils in Singapore started the project at a very high level of attainment and continued to make fast progress (despite the fact that each test paper had only 50 marks available and many pupils at the first round of testing scored exceptionally high marks, making it difficult for them to show progress over the next two years), so it was important for us to find out why and how.

The first and most obvious answer was that pupils in Singapore worked very hard, and not only in the classroom; typically they would continue to work (either with the help of parents, private tutors or extra group tuition) after school, so they had considerable practice in any mathematical concept covered. This was illustrated by the number of exercises set on each topic, probably about five times the amount set on a similar topic in a British textbook. There were, though, other factors which also seemed pertinent:

- whole class teaching in large classes, but with little interaction;
- extensive practice in class (as well as in homework);
- correct, precise use of mathematical language and notation;
- clear structure of what was to be taught when, supported by comprehensive resources – teacher support, pupil texts and practice books (for homework);
- low ability pupils took a lower national qualification (N-level) at age 16+, and had an extra year's schooling before taking O-level Mathematics[3];
- although calculators were readily available, they were used only for trigonometry or very complex calculations and were not needed for straightforward calculations involving decimal numbers or fractions;

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1 All pupils were given a Formulae Sheet for this test but pupils in Singapore and Hungary did not need to use it, as all key results had been learned by heart and practised regularly.

2 Hungarian pupils did attempt the *Handling Data Test* and scored on average about the same as English pupils.

3 Typically, over 80% of the cohort eventually passed O-level Mathematics

Finally, it was interesting to note that some teachers and educationists in Singapore were beginning to question the apparent success of their pupils in mathematics and wanted pupils to gain other skills such as creativity, applying mathematical concepts[4], problem solving and investigational work, rather then concentrating on practising the limited (but impressive) range of skills needed for the 'closed' type exam questions.

b) HUNGARY

When the researchers first visited Hungary to see mathematics teaching, they had already experienced maths teaching in Germany, but even this prior experience did not prepare them for the radically different strategies seen in nearly all Hungarian classrooms[5] visited.

In Hungary, there is streaming rather than setting and, in most areas, by the age of 14 pupils are in one of three streams:

- **Academic** – with the aim of continuing on to University;
- **Technical** – more practically based but still a possible route into higher education;
- **Vocational** – with certain schools specialising in particular vocations (e.g. catering, tourism, agricultural, mechanics, etc.) and half the time spent in local employment, half in school.

The mathematics curriculum is specified for each stream from age 14 years. However, what did surprise us was that the same teaching strategies were employed at all levels:

- whole-class **interactive** teaching interspersed with short periods of individual work and with a strong whole class ethos;
- pupils working cooperatively together, helping each other and discussing mistakes openly without embarrassment or derision;
- lessons orchestrated and controlled by the teacher, but in a non-confrontational manner so that pupils were happy to play a more active role in their learning – demonstrating on the board, explaining solutions, offering alternative methods, pointing out mistakes and seeking clarification when required.

Other points which seemed important were:

- precise, correct mathematical language and notation was used at all times;
- homework was reviewed interactively at the start of each lesson;
- exercises were set and reviewed one at a time, so that the whole class was always working on the same problem;
- pupils sat in pairs facing the board, less able with more able, as decided by the teacher;
- teachers closely monitored the progress of <u>all</u> pupils throughout the lesson;
- as in Singapore, there was little use made of calculators, except in trigonometry, and no need for formulae sheets.

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4 Interestingly, an optional test in the Kassel Project was the *Applied Maths Test*, which was taken by some countries, including Singapore. All Singapore pupils who performed well on this test also did well in the *Topic Tests*, but a significant number of pupils who did well in the *Topic Tests* had disappointing results on the *Applied Maths Test*. The same result was true of English pupils.

5 One Hungarian class visited was trying to implement 'American-style' teaching, which was identical to that seen in most English schools at the time – individualised learning, with pupils sitting in groups around tables and each group doing different activities.

What seemed crucial was the underlying feeling of trust and cooperation, with the clear understanding that pupils were there to work and to make progress.

The second surprise was the high level of mathematics being taught and understood, even in Vocational classes, where relevant contexts were used throughout. Given the level of attainment in the *Kassel Project* tests, this should have been expected but nevertheless it was impressive to observe both the confidence and competence in mathematics shown by Hungarian pupils. Of course, it was apparent that this high level of attainment and confident attitude towards mathematics was due not only to secondary maths teaching but also to mathematics education in primary school. Therefore we asked whether we could observe some primary mathematics lessons; all were equally impressive and, as in the secondary schools, whole-class interactive teaching was the main teaching style.

In summary, what we saw in Hungary, backed up by the attainment data, was very exciting and despite all the problems associated with importing a teaching philosophy from one country to another, we felt that we had much to learn from Hungary and, if possible, to put into practice in schools in the UK. It should also be noted that what we have written about Hungary could equally well have been written about Poland, Czech Republic, Russia and Ukraine, since all followed very similar teaching strategies.

Each country coordinator in the *Kassel Project* had a brief to make recommendations for mathematics teaching for their particular country (and eventually, in the final report (6), we will bring these recommendations together where possible as a set of international recommendations for mathematics teaching). The recommendations which we made (with the help of the other country coordinators who had seen mathematics teaching in the UK), are given in **Appendix 1**. They followed from the observations and commentary given above, although some (such as the encouragement of GCSE Statistics and the revision of tiering at GCSE) were obviously based only on national evidence.

Towards the end of the British phase of the Kassel Project, our main funders, *The Gatsby Charitable Foundation*, encouraged and supported the idea of putting these recommendations into practice in schools in the UK. This was the start of the ***Mathematics Enhancement Programme (MEP)***.

3. Mathematics Enhancement Programme: Secondary

a) Planning Year

Implementation required some difficult decisions to be made, particularly as at the time we could anticipate funding for only 3 years. We decided to :

- follow two cohorts of pupils through years 10 and 11 to GCSE exams, the first starting in September 96 and the second in September 1997, thus allowing us to monitor teachers who would be more familiar with the pedagogy and material;
- offer English schools which had participated in the Kassel Project the first chance to join the project, followed by schools in the South West where we had contacts and a selection of schools which were already participating in the *Technology Enhancement Programme (TEP)* also funded by the Gatsby Charitable Foundation;
- produce videos of good practice in mathematics teaching in Hungarian primary and secondary schools (principally funded by OFSTED) for use on inservice courses;

- develop comprehensive pupil and teacher resources, as we felt that the current texts and support were not particularly helpful in encouraging the highly interactive style of teaching that we wished to promote.

We ran three regional workshops (in London, Leeds and Exeter) in which about 120 schools participated. Of these, 95 schools agreed to join the project (although not all as full project schools – some schools agreed to try out the teaching style using their current resources, and others to cherry-pick from the recommendations).

Volunteers were recruited to form working groups to develop the scheme of work, coursework activities and material for low attainers, although only an enlarged scheme of work group continued to meet regularly.

Our research into the most effective resource provision led us to adopt the Singapore framework of:

- **Schemes of Work** (in outline and in detail) for 4 ability levels relating to GCSE tiers[6]:

GCSE Tier	Route
Higher	*Express* and *Special**
Intermediate	*Academic*
Foundation	*Standard*

The material to be covered during years 10 and 11 was divided into 19 units of work (**Appendix 2**) and students, whatever their route, took the appropriate sections in each unit; we hoped that this would facilitate transfer from one route to another.

- **Pupil Texts** with clear diagrams and written text designed to support teaching rather than to be used without a teacher. Gimmicks such as speech bubbles, coloured pictures, cartoons, etc. were not used as we wanted the text to be produced in a clear, straightforward, attractive style[7]; each section of work consisted of introductory text, worked examples and exercises, with answers provided at the back of the book and thought-provoking extension material.
- **Practice Books** containing another set of parallel exercises (including exam questions) for each section of work and designed for homework use, so answers were not provided.
- **Teacher Support** for each unit of work, consisting of:
  - historical notes and background information
  - misconceptions
  - routes through the material (**Appendix 2**)
  - brief lesson plans
  - activities for more in-depth work leading to coursework

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6 We put forward a proposal for a pilot non-tiering GCSE but this was turned down by SCAA, the regulating authority, although we were given permission to experiment with a non-operational version. (7)

7 The *MEP* logo, front covers and layout were designed by Clinton Banbury.

– copy masters for overhead transparencies in order to encourage student participation at the front of the class
– mental and revision tests
– answers to the practice books.

The 19 units of work were divided into three parts (Units 1–6, 7–12 and 13–19) with a separate pupil text and practice book for each part. The same texts were used by all pupils (appropriate sections being selected for the specified route) but the practice books were differentiated on two levels – *Standard/Academic* and *Express/Special*.

We also produced

- comprehensive resources to support the Welsh Board's Certificate of Education for low ability pupils;
- resources to cover the extra material needed for GCSE Statistics beyond that already in the general mathematics course.

Much of the work in the preliminary year focused on setting up the framework and producing resources, rather than preparing teachers in project schools for interactive teaching. The first six units were piloted and dispatched to schools for use at the start of the term in September 1996 and each school was sent copies of the videos of good practice based on Hungarian lessons.

Schools were encouraged to undertake the Kassel Project tests with all project pupils as a baseline measure at the beginning of Y10 before any *MEP* teaching began. Although this meant that the *Potential Test* was taken one year later than in the Kassel Project, the *Topic Tests* used were exactly comparable and enabled us to use the Kassel Project cohort as a control group.

b) YEAR 1 (1996–7)

During the year, many, but by no means all, schools were visited, lessons observed and feedback given verbally directly after the lesson and also as a written report (see **Appendix 3**). On the whole, we were encouraged by what we observed. Many teachers were trying to implement the strategies although others seemed reluctant to do so. They gave various reasons for this:

- reluctance to change teaching strategies which they had used for many years;
- not confident enough to be exposed in the way that *MEP* was encouraging;
- unwilling to take any risks, particularly as the classes involved would sit national exams (GCSE) at the end of the course.

It was undoubtedly true that in the majority of schools, students were not used to speaking or writing mathematically or to taking part in whole class discussions. Also, many teachers found the expected pace and level of work too demanding at first, with too much content to cover in the time available[8]. For example, many teachers were reluctant to ask pupils to demonstrate at the board in front of the class as they thought pupils of that age were too old to change their ways, but other teachers fully embraced this aspect of the

8 This was often because teachers felt that they had to cover everything and pupils had to do every exercise, which was certainly not the intention of the project team.

teaching philosophy and the positive, collaborative ethos of their classrooms reflected this increased interaction.

Discussions with teachers tended to centre on the resources, particularly as we had attempted to raise expectations and many teachers and pupils found *MEP* tough going in terms of content and pace, but teachers were reluctant to discuss in any detail the impact of the teaching philosophy, a fact which caused us some concern. However, in general, we were pleased with much of what we observed and looked forward to further advances being made in both Cohort 1, Year 11 and Cohort 2, Y10.

One aspect which did surprise us was the rapid turnover of staff in many schools. This necessitated the running of inservice courses during the summer term of 1997 for all new teachers in project schools.

At the end of the first year, we collected evaluation evidence through *Teacher* and *Pupil Questionnaires*. Responses were encouraging (8); for example from the *Pupil Questionnaire*:

Has MEP succeeded in raising:

a)	*your level of understanding of basic concepts?*	YES 84%	NO 16%
b)	*your own expectations of what you can do?*	YES 75%	NO 25%

Most pupils felt that their mathematics lessons had changed:

Have your maths lessons changed with the introduction of MEP?

Completely (8%), A lot (39%), A little (48%), Not at all (6%)

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and these responses tallied with our observational experiences. Pupils were also very positive about the texts:

Do the MEP textbooks explain maths more clearly than your previous textbooks?

Much better (39%), A little better (37%), The same (15%), Worse (9%)

The features of the text pupils liked best were the worked examples, clear explanations and setting out of working. Pupils felt that algebra was the most improved part of their mathematics but also that it was the topic which still needed most improvement.

Another question which received fascinating responses was about absence:

If you missed a maths lesson, how did you catch up?

Copied from a friend (34%), Caught up at home (11%), Asked the teacher (10%), Asked a classmate (9%), Did not catch up (9%)

These responses appeared to be in conflict with the responses from an equivalent question on the *Teacher Questionnaire*:

If pupils were absent, how did they catch up?

Help given by the teacher during breaks or at lunch-time. (16%)

Individuals given help in class (11%), Pupils copied from a friend's notes (10%)

There is a potential dilemma here, as mathematics is a very linear subject and the *MEP* teaching style makes the teacher's role even more crucial. Missing just one lesson can cause a problem and the *ad hoc* arrangements made for pupils to catch up, particularly the reliance on using 'friends' according to the pupils, is perhaps not sufficient to provide the required backup for pupil absence. There is also the related problem of teacher absence but we will deal with that issue later.

On the whole, teachers were also positive about the impact of *MEP*, as can be seen from the response to this question at the end of the *Teacher Questionnaire*:

In your opinion, has MEP succeeded in raising:

a)	*your own expectations of what your pupils can do*			YES 69%	NO 31%
b)	*your pupils' level of*	*i)*	*attainment*	YES 80%	NO 20%
		ii)	*understanding?*	YES 82%	NO 18%

30% of teachers said that they had made substantial changes to their teaching style, although 6% admitted that they had not changed their style at all (and from our observations this was <u>not</u> because they were already teaching in the *MEP* way).

We had encouraged teachers to spend time on mutual observation and departments to visit other *MEP* schools to observe teaching but responses from the *Teacher Questionnaire* made it clear that this was not really happening. We were keen that the most effective teachers should be observed by others, but in practice this was not the case.

Another issue which generated much discussion and feedback was how appropriate *MEP* was to pupils in the lower sets, including non-GCSE classes. The great majority of teachers were united in saying that *MEP* (teaching style and resources) was really for the top and middle sets and not for the lower ones, as the resources were too ambitious and the teaching strategies, particularly the encouragement of pupils to work at the board in front of the class, were not suitable. Teachers were very reluctant to lose control of a class which, given the chance, could cause mayhem! However, in several such classes

we saw *MEP* working extremely well, even with the result that these students had improved their attendance at school due to *MEP* mathematics lessons! This result was not universal but it brought home to the researchers that all pupils, whatever their ability, need to be positively engaged and challenged and not just kept quiet.

c) YEAR 2 (1997–8)

In September 1997, a second Y10 cohort started *MEP* while the first cohort moved on to Year 11 and began to prepare for GCSE. The sequence of topics in the 19 units of work had been designed so that there was emphasis on algebra in the early units and, once over the first few units, the course appeared to become easier. Some teachers were concerned about this and changed the order of units, but in general the original order of units seems to have worked well.

Value-added measures were computed for those pupils in Cohort 1 who had taken the Kassel Project tests at the beginning of Years 10 and 11. Here we were measuring the progress from Y10 to Y11 but referencing this to the earlier Kassel Project database (i.e. a control group but from a previous year). Value-added scores are given in **Appendix 4** and show considerable variation, but generally they point to an enhancement over the Kassel Project data.

The value-added data, as it became available in the early part of the year, indicated where to observe and we concentrated on schools and classes at the extreme ends of the data. There was a good correspondence between classes in which teachers were attempting the *MEP* teaching style in a positive way and progress; that is, pupil progress and effective implementation of *MEP* teaching strategies correlated positively.

One teaching strategy regarded by the researchers as important for effective *MEP* teaching was that of students working at the board in front of the class in order to achieve a positive whole-class ethos, but it soon became clear that pupils just going to the front and writing on the board was a naive interpretation of what was intended; what we wanted to see was the student also explaining his or her reasoning, the class agreeing or disagreeing and the teacher or class pointing out errors immediately and discussing alternative methods of solution or common misconceptions.

A similar situation occurred with questioning. Some teachers thought that asking lots of questions with straightforward answers was good interactive teaching; we explained that there should also be more challenging questions which encouraged creative thought and critical discussion.

To help schools appreciate the qualities and strategies we wanted to see, we provided a lesson checklist which is given in **Appendix 5**. It is not clear how useful this has been to *MEP* teachers but it has certainly proved useful to the researchers in their lesson reviews.

Other problems which became apparent were the following:

- there was a reluctance to accept the short but regularly set homework, spanning one lesson to the next; many schools' homework policy did not allow this and teachers had to set homework once or twice a week, collect in, mark and return some time later but other schools managed to persuade their Heads that this was an important aspect of the *MEP* strategy;

- the Hungarian use of exercises is to go through them one by one, with the teacher monitoring individual work thoroughly and knowing exactly what every pupil is doing before reviewing solutions interactively, usually on the board, and openly discussing problems; teachers in project schools tended to keep to the traditional British style of setting questions 1–10 and the teacher going round helping pupils who put their hands up; in retrospect we should have stressed this aspect more in our recommendations;
- whole class interactive teaching was made more difficult by a number of problems:
  - it was important that all pupils were seated so that they could see the teacher clearly and get to the board easily and that the teacher could get to all pupils with ease but this was just not possible in many cramped and badly designed classrooms;
  - for *MEP* teaching to be effective, it is essential that teachers have a good quality, extensive board but again, this was often not the case; nor were teachers using board equipment as we had recommended – we wanted board work by the teacher (and pupils) to be a model of clarity and precision for pupils to follow and imitate;
- teacher absence seemed to be a problem in many schools and the use of supply cover familiar with *MEP* style teaching was clearly not possible, so for such classes the pace and rigour of *MEP* was lost; teacher mobility was already an issue and many new teachers were coming into schools with little or no knowledge of *MEP*[9], and several Heads of Departments left taking all knowledge of *MEP* with them;
- a few departments were not united in their support of *MEP,* which was unfortunate because team discussion and collaboration were important for implementing changes in teaching strategies.

The research team at CIMT managed to visit some, but by no means all, project schools during the first two years. We assessed how effective teachers were in implementing *MEP* and it was of interest to compare our initial assessments with the enhancement in GCSE grades obtained, comparing not only with the school's own previous year's results (which we will call Cohort 0) but also with the predicted grades for schools which had taken the Kassel Project tests.

The resulting analysis of candidates obtaining grades A*–C from Cohort 0 to Cohort 1 (and Cohort 2 which came the following year) is illustrated in ***Fig. 2***. We have also included the same analysis for three particular schools on which we will comment later. It should be noted that the national percentages of pupils aged 16+ achieving each grade in GCSE remained essentially static during this 3-year period. So, without intervention, we would expect no change from Cohort 0 in the percentage of grades A*–C. The data in **Fig. 2** are based on over 40 schools, with almost 7000 pupils in total.

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9 We had expected that Heads of Department would take a lead here, but they often seemed reluctant to do so; we again had to offer a number of regional inservice courses for new teachers but were surprised that they were still necessary so far into the project.

Fig. 2:

Overall, there was an increase in this measure and it became more significant when we considered only those schools which we had judged to be implementing *MEP* effectively. In general, there was an increase of about 6 percentage points from Cohort 0 to Cohort 1 in these schools).

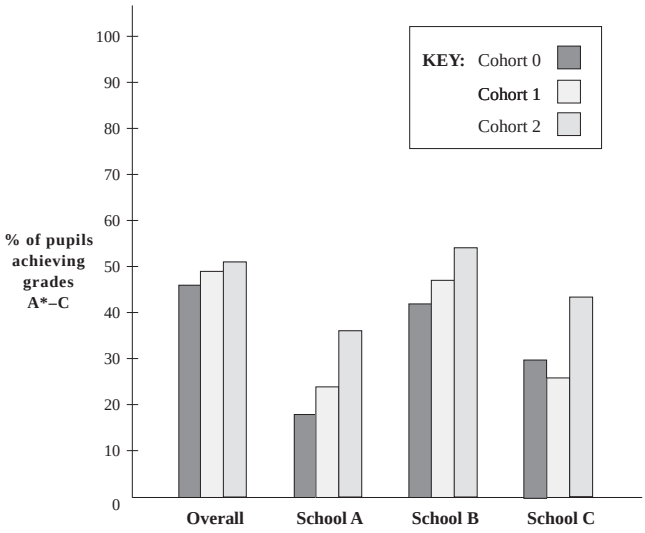

Fig. 2: Comparison of GCSE grades achieved by MEP schools

Initially, we rated schools on a scale of 0, 1, 2 according to how effectively they were implementing *MEP* but eventually we discarded this method in favour of tracking the teachers who were using *MEP* strategies most, and least, effectively. This is considered in more detail in the next section.

After the first testing at the beginning of Year 10, we were also able to compute grade predictions for each pupil, based on the Kassel Project outcomes at GCSE, and to compare these predictions with the grades actually achieved. Again, the results were encouraging, with *MEP* classes which we ranked highly averaging about half a grade higher per pupil and all *MEP* pupils averaging an increase of about one quarter of a grade.

It is interesting to note in ***Fig. 3*** the results from a school where we had observed some teaching in Year 10 and Year 11 and had given some teachers a high ranking in their implementation of *MEP*.

		Grade predicted (achieved)									
Set	**No. of Pupils**	**A***	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**U**	**Difference**
1	27	2 (2)	4 (14)	13 (9)	6 (2)	2 (0)	–	–	–	–	+ 18
2	27	–	0 (1)	2 (17)	20 (8)	4 (1)	1 (0)	–	–	–	+ 22
3	23	–	–	–	8 (14)	10 (8)	5 (0)	0 (1)	–	–	+ 8
4	25	–	–	1 (0)	10 (4)	8 (14)	6 (6)	–	0 (1)	–	– 15
5	19	–	–	–	3 (3)	5 (6)	9 (8)	2 (2)	–	–	– 1
6	12	–	–	–	–	–	6 (4)	6 (6)	0 (1)	0 (1)	– 5
	133	Average gain per pupil ≈ 0.2 of a grade									**27**

Fig. 3: Comparison of predicted grades and grades achieved

Fig. 3 summarises the difference between predicted and achieved grades (the latter shown in brackets). Counting each grade increase as 1, the final column gives a summary for every set. (For example, a pupil who had been predicted Grade D and actually achieved Grade B would count as +2 on this measure.) The first three classes had substantial gains

in GCSE grades but Sets 4 to 6 were disappointing, leading to an overall grade increase per pupil of only 0.2. However, as is the case with most schools, there were peculiarities which could be explained or interpreted only when we had obtained more information.

We had visited the school in Year 1 of the project and had noted that Set 6 was neither using *MEP* resources nor implementing any of the recommended teaching strategies (in fact, pupils were using an individualised scheme). It was only later that we learned of the disaster that had befallen Set 4; the Year 10 teacher had left suddenly, no permanent replacement was appointed and a succession of supply teachers had been used for the remainder of that academic year. The results of this are all too obvious from the data.

We also had *Pupil Questionnaires* for a stratified sample (not necessarily representative) of pupils taken immediately after they had sat GCSE exams. It was reassuring to note the responses to this question:

How similar were the majority of questions to the MEP exercises?

Very similar (8%), Quite similar (84%), Very different (8%)

The responses to the following question were also interesting:

Ho much support did you receive from your school?

A lot (60%), A little (36%), Not much (4%), None (0%)

Finally, we had in response to the Year 11 course:

- *Have you enjoyed your mathematics lessons in Year 11?*

  A lot (21%), A little (51%), Not much (21%), Not at all (7%)
- *Have you worked harder in Year 11 than you did in Year 10?*

  A lot harder (28%), A little (48%), The same (20%), Less hard (4%)
- *Have you taken more responsibility for your learning in Year 11 than in Year 10?*

  A lot more (37%), A little more (43%), The same (18%), Less (2%)

These responses showed some success with some pupils but we felt that much more work had to be done in convincing teachers to implement the *MEP* strategies more fully and also we realised that pupils needed more time to become accustomed to the high level of involvement expected on their part, rather than the passive learning to which they had been accustomed in previous years.

d) YEAR 3 (1998–1999)

The initial success of *MEP* and the keenness of many project schools to implement the strategies with their Y7–9 classes prompted us to move our focus to designing a Key Stage 3 course (Years 7–9). At the same time, we began to implement a similar initiative in a few partner primary schools (**Section** 4).

In the light of our lesson observations, we felt we needed to fine-tune (but not change) the recommended strategies, so we produced a list of *MEP* teaching strategies which summarised the detailed advice we had been giving to teachers after lesson observations. Teachers were encouraged to promote this teaching philosophy in the lower secondary years and also in mathematics lessons in their partner middle and primary schools.

The revised general recommendations were:

- a planned combination of interactive, whole class teaching and individual work;
- teaching with pace, enthusiasm and humour, continuously monitoring the progress of all pupils;
- clear, precise description of topic or concept being taught;
- high quality interaction with a whole-class ethos, pupils working at the board explaining their reasoning and all pupils kept on task;
- mathematics correct, precise and logical at all times, whether spoken or written;
- mistakes used as teaching points with the whole class;
- emphasis on mental work, particularly in the early years;
- limited calculator use, and only when pupils have gained competence in basic numeracy;
- applications and meaningful investigations used only when appropriate;
- clearly specified schemes of work;
- setting from Year 7 onwards;
- homework
  - used as an integral part of the learning
  - bridging one lesson to the next
  - reviewed interactively at the start of the next lesson;

but above all

- putting the teacher back as the orchestrator of the learning throughout the lesson.

More specific advice given to teachers was that they should also:

- prepare lessons well and have all equipment and materials to hand;
- work through any questions or exercises beforehand to ascertain where problems might arise;
- regularly test pupils' knowledge and revise topics causing problems;
- relate mathematics to pupils' experiences and the world outside the classroom;

- be aware of what every pupil is doing at all times;
- discuss common errors before too many pupils have made them;
- revise forgotten or misunderstood concepts immediately there is a problem;
- involve as many pupils as possible in contributing to the lesson and working at the board;
- question effectively, leading pupils to think for themselves;
- monitor individual work thoroughly and effectively;
- praise creativity and good work;
- manage the lesson time well;
- summarise the main points at the end of the lesson.

Seventy schools agreed to participate in the Key Stage 3 phase and we used a similar structure for resource provision as in Years 10 and 11, but with some important modifications, for example:

- we used the framework of *Practice Book* and *Teacher Support* but the practice book was an amalgamation of the Pupil Text and Practice Book in Y10 and 11, with extra exercises available on the internet;
- in fact, the internet (using .pdf files in *Adobe Acrobat*) provided us with a cheap and effective way of disseminating the teacher support material, and for completion we also put the practice books[10] on the internet; project schools were encouraged (and eventually forced) to obtain the teacher support from the internet while practice books (2 per year) were provided free of charge;
- the schemes of work group continued to provide the detailed content[11], and there were three routes through the material (Standard, Academic and Express) with easy transition from one route to another;
- the practice books provided only a brief introduction to topics and concepts, as we were keen to encourage the interactive style of teaching rather than providing resources which could be used on a stand-alone basis;
- in the first year of this extension we videoed lessons in *MEP* schools to provide a new *MEP* teaching video; reaction to this video, which did not reach schools until the end of this year, was very favourable.

Tests were produced for use at the beginning of Year 7 and Year 8 (based on appropriate questions from the Kassel Project tests) in order to assess mathematical potential and current attainment. They were designed with the expectation that incoming pupils might, in a few years' time, show increased attainment due to the impact of the National Numeracy Strategy and the increased emphasis on attainment in primary schools. Consequently, many schools were unhappy with the tests, either because of their structure and content (which, unless pupils were specifically told that the tests were designed to measure progress and hence not to be concerned if there were questions that they could not attempt, were rather daunting) or because the school was also using other (commercial) tests on entry. (All schools were asked to undertake the testing with Year 7 pupils in Cohort 4 and to explain to pupils the reasoning behind them.)

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10 In order to provide non-project schools with the complete set of resources

11 As with the Y10 /11 initiative, the first draft of these resources was provided by Dr.Ted Graham of the Centre for Teaching Mathematics, University of Plymouth

We do, though, have Y7–8 progress data from 41 schools and these are summarised in **Appendix 6**. Here the value-added measure is based on comparing individuals with the progress made by groups of pupils with similar starting points at the start of Year 7. They illustrate a number of interesting points:

- there were wide variations among schools and within schools;
- there was little correlation with the value-added measures of schools which had also participated in Cohorts 1 and 2 (Y10 to Year 11);
- there was a strong positive correlation of potential with progress.

We had encouraged schools to set early in Year 7 but it should be noted that one of the best performing schools did not set in Year 7. This is a key area for future research.

The *Pupil Questionnaire* given at the end of Year 7 is also very supportive of *MEP*, particularly responses to the following questions:

A1 *Have you enjoyed the MEP whole-class teaching style?*

Very much 22%, Sometimes 53%, Don't mind 21%, Not at all 4%

C1c *Does this book explain the maths more clearly than your previous maths books?*

Much better 43%, A little better 39%, The same 14%, Worse 4%

D5 *Do you think you have gained confidence in maths this year?*

A lot 40%, A little 44%, The same 13%, Less confident 3%

E2 *Has MEP succeeded in raising:*

a)	*your level of understanding of basic concepts?*	YES 91%	NO 9%
b)	*your own expectations of what you can do?*	YES 86%	NO 14%

It is also interesting to note the almost identical responses to these questions:

A7 *Which part of your maths work has improved most over the year?*

Fractions 16%, Decimals 12%, Times tables 11%

A8 *Which part of your maths still needs improving?*

Fractions 15%, Decimals 12%, Times tables 12%

Finally, we are still concerned about what happens when pupils miss a lesson; this concern is illustrated by the following responses:

A9 *If you missed a maths lesson, how did you catch up?*

Copied from a friend 17%, Caught up at home 14%, Asked classmates 14%,
None missed 11%, Asked the teacher 9%

It is worrying that only 11% of pupils did not miss a maths lesson and of those who did only 9% asked the teacher for help. We plan to address this problem by eventually providing interactive versions of *MEP* units on the internet but in the short term some common strategies must be devised.

As this is a long-term initiative to raise mathematical thinking and attainment, we did not feel it necessary to have a control group because data from results at Key Stage 2 and Key Stage 3 could be used to measure long-term progression and to compare with national results (in effect, the control group would be all other schools taking Key Stage 2 and Key Stage 3 tests). Also, we felt that we had sufficient evidence both from other countries and our demonstration project in Years 10 and 11 to know that effective implementation of the *MEP* teaching philosophy worked and did indeed produce substantial gains on national examinations. More important questions for us were:

- What support (e.g. inservice, videos, observations) is needed so that teachers adopt the strategies completely?
- Why do some teachers understand and are able to put into practice the *MEP* strategies while others, with identical inservice support, framework and materials, fail either to understand or to implement the strategies?
- How can heads of departments help new teachers to implement *MEP* effectively?
- How can we persuade teachers to share experiences and, in particular, gain from seeing effective *MEP* teachers in action?

All these questions seemed far more important than 'Does *MEP* work?', which was the line increasingly being taken by our main funder of the secondary phase[12].

One extra initiative at this stage was the development of regional self-help groups, led by experienced, skilled *MEP* teachers in schools which had been shown to be effective by test data and lesson observations. It was planned that these groups would meet regularly, would encourage joint inservice, would provide a contact point for non-*MEP* schools interested in adopting the teaching philosophy (of which there were many) and would initiate joint observations. However, their effect has been patchy for a number of reasons:

- heads of department have very little free time for this type of activity;
- we did not provide direction for the work of these groups but rather expected them to set their own agenda;
- in some regions, participating *MEP* schools were located close together but in other areas they were very far apart and this certainly did not aid collaboration.

Despite this, significant collaboration did take place but it was most effective in areas where there was a group of local *MEP* schools (secondary and primary) working together.

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12 Partly to satisfy the requirements of our funding body and partly to ensure the continued provision of free resources to project schools, we agreed to a revised evaluation strategy at the end of the first year of the Y7–9 initiative in which CIMT would continue to provide feedback, both from test data collected and lesson observations but there would also be an independent evaluation, directed by Professor David Reynolds.

It will be interesting to see how schools react to this change of emphasis as we have gained from having a close working relationship with project schools, emphasising collaboration on problems and difficulties.

In summary, we have been pleased with the response of schools to this initiative, although we are still concerned that not all teachers have adopted all the recommended teaching strategies and are worried that the recent extension of the Government's Numeracy Framework to Key Stage 3 might muddy the waters, as some schools will undoubtedly feel that they must adopt the Numeracy Framework in its entirety rather than see *MEP* as an effective way of delivering the strategy. Also, the current emphasis on numeracy strategies for Key Stage 3 and numeracy recovery programmes might encourage the view that numeracy is different from mathematics, whereas all our international research supports the contrary view that effective numeracy derives from a sound foundation in mathematics.

At the start of this year, we also obtained value-added data for progress by Cohort 2 in Year 10 (**Appendix 6**). It is of interest to note the following.

1. The overall value-added measure (based on Kassel Project data) does improve from Cohort 1 to Cohort 2; this was partly due to a small number of schools which did not achieve high value-added scores in Cohort 1 showing significant improvement in Cohort 2, as teachers became more familiar with the material and more accustomed to the style of teaching.
2. The improvement was small and the two sets of data show significant positive correlation (with a value of 0.6 for the product moment correlation coefficient).

The national GCSE data for Cohort 2 became available at the end of this year and broadly followed the pattern for Cohort 1. ***Fig. 2*** gives the overall results but masks the large variations in some schools, which were not necessarily linked to the implementation of *MEP*. As before, there was a small but significant gain in the percentage of pupils achieving Grades A*–C and schools where teachers were implementing *MEP* most effectively had the largest gains. ***Fig. 2*** highlights three schools, each with its own characteristics.

School A

This is a comprehensive (11–16) school in a very deprived area. Over two years, the increase in the percentage of pupils achieving Grades A*–C doubled: 16% in Cohort 0 to 24% in Cohort 1 to 36% in Cohort 2. Interestingly, the school had not undergone any radical changes in its entry pattern, the teaching staff had remained static and the implementation of *MEP* appeared to be the crucial factor in the increase in attainment.

School B

This is a comprehensive (11–18) school in a pleasant country town. The impact on Cohort 1 (42% to 47%) was substantial and continued into Cohort 2 (54%), although this was partly helped by the appointment after the first year of *MEP* of a young, dynamic head of department.

School C

This illustrated some of the wilder variations, with a dramatic drop (from 30% to 26%) in Cohort 1, which at least in part reflected some of the problems of implementing *MEP* with weak teachers. However, the following year (again due to a more effective implementation of *MEP*, but which included significant changes in staff and class allocations) there was a leap to 43% and this was predicted by our test data after good progress in Y10.

4. Mathematics Enhancement Programme: Primary

a) INTRODUCTION

Our earlier visits to countries such as Hungary, Poland and the Czech Republic showed not only that their secondary pupils had higher attainment but also that this must in part be due to their mathematical experiences at primary schools. So, both during the Kassel project and afterwards, we spent time observing primary mathematics teaching in these countries and studied their frameworks, resources and training.

First of all, we were surprised to see primary classrooms designed in a very formal way, with children sitting in pairs at desks in rows facing the teacher and board, which of course made it

- easy for pupils to see the teacher without having to strain their necks or backs;
- easy for the teacher to focus on all pupils;
- straightforward for pupils to come to the front to demonstrate or explain;
- easy for the teacher to reach any pupil quickly.

Classrooms had good boards (often with side flaps), exact number lines were displayed so that pupils could see and touch them easily and number cards were used for quick responses to mental work. Above all, the same type of whole-class, interactive teaching as we had seen in secondary classrooms was used as the main teaching strategy, with pupils actively involved throughout and with a series of activities along a main theme during the lesson. There was little or no group work as differentiation on the whole came through outcome, not task, with teachers again orchestrating the activities and putting enthusiasm, humour and pace into their lessons. The result was a curious mix of rigour, excitement and fun!

Other aspects which seemed important were:

- pupils started primary school one year later (at age 6+), after normally having two years in Kindergarten, which aimed to prepare pupils for primary school by concentrating on
  - verbal skills
  - listening
  - concentrating
  - sitting still
  - following instructions

  rather than on mathematical topics (although numbers up to 10 were covered but not written at this stage);
- daily 45 minute mathematics lessons, early in the morning;
- the mathematics curriculum and activities were based on providing a sound mathematical foundation, emphasising notation, logic and concepts, rather than rushing on to large numbers, e.g. in Year 1, only numbers 1–20 were covered but notation for inequality was brought in alongside the equality sign;
- number cards were used extensively in the early years for quick responses to number work, so that teachers could quickly assess the whole class;
- effective numeracy skills were derived from a strong mathematical base;

- preparation for algebra could be seen in exercises such as $7 + 8 = \square$, where the verbal answer expected was 'seven plus eight equals fifteen' rather than just '15';
- all primary teachers from Year 1 onwards had a sound grasp of mathematical concepts (which was at least in part due to studying mathematics in a broad sixth form course before entry to teacher training institutions);
- pupils struggling with mathematics were given extra practice in the afternoon in place of other activities, because mathematics and Hungarian were regarded as much more important subjects.

At that time (1994–1996), this contrasted sharply with the rather irregular pattern of maths teaching in primary schools in the UK, where there was a strong investigational approach, group work dominated, mental work was not always encouraged, calculators were used unrestrictedly and there was little or no whole-class teaching.

Although we were enthusiastic about the initiatives we were implementing at secondary level, it soon became apparent that long-term success would depend on making significant changes at primary level. When we videoed secondary lessons for *MEP* we took the opportunity also to video Reception and Year 1 classes in Hungary. This proved to be very expedient and these videos have probably had more effect on practice than any other videos produced in recent times on mathematics teaching.

Initially we used these videos to inform primary teachers about the strategies which we thought would enhance primary mathematics teaching in the UK. In collaboration with Professor Ruth Merttens, a *Blueprint for Numeracy* was published in *The Sunday Times* in 1997 (see **Appendix 7** for a summary). At the same time, the then Government set up a pilot 'numeracy project' directed by Anita Straker and the incoming Government quickly set up a Numeracy Task Force (of which the *MEP* director was a member).

Many of the recommendations we wished to see were incorporated into the *National Numeracy Strategy* (9), although in practice the national roll-out to all schools emphasised aspects which seemed at variance with good practice we had seen in other countries. In particular, a 3-phase lesson structure was given high prominence:

Phase 1: mental practice
Phase 2: differentiated group work on a main activity
Phase 3: plenary session

with about half the time given to *Phase 2*. The strategy actually allowed a variety of activities in *Phase 2*, including a continuation of whole-class, interactive teaching. Of course, if the lesson did continue with whole-class, interactive teaching and individual work in *Phase 2*, the plenary phase would be subsumed as the class would have been working together for most of the lesson.

b) YEAR 1 (1998–9)

In September 1998, *MEP* was extended to 40 volunteer primary schools which fed into 10 established *MEP* secondary schools. As we realised the extent of the changes we were expecting primary teachers to make, we decided to

- start at Reception and Year 1 and implement year by year over a 6-year period;

- provide detailed resources[13], including
  - practice books (**Appendix 8**)
  - detailed lesson plans (**Appendix 9**), so that teachers would be fully aware of what we expected to take place in their classrooms.

We had little support locally apart from the secondary coordinators who, of course, could provide enthusiasm and help but, on the whole, could not be regarded as primary maths experts, particularly in Year 1. Initial inservice was given to all Reception and Year 1 teachers involved (but usually only one afternoon session or a couple of after-school meetings).

The implementation was characterised by

- some teachers radically changing their teaching strategies (usually by following the lesson plans closely) with great success;
- other teachers struggling, for example using the number cards but finding the books and lesson plans too difficult and inappropriate;
- yet others, who were experienced teachers and had already moved in this direction, modifying their lessons but not even attempting the detailed lesson plans.

Many teachers (and schools) were reluctant

- not to have substantial amounts of time devoted to differentiated group work[14];
- to move seating into a more effective configuration for whole-class interactive teaching[15];
- to raise their expectations of what their pupils could achieve.

We were also keen to follow the sequence of topics, including notation, used in countries such as Hungary so that

- the correct mathematical language was used from the start;
- notation for inequality (<, >) was introduced at the same time as for equality (=) and used precisely and correctly at all times.

Although few pupils had problems with this, many Year 1 teachers did not feel confident about this concept (in retrospect, we should have provided more initial support).

It was unfortunate for *MEP* that the *National Numeracy Strategy* was also being developed at the same time and during 1997 its strategy document and some initial training was given to head teachers and mathematics coordinators. For many head teachers, *MEP* appeared to be in conflict with the *NNS* as this was the message being given by local numeracy consultants. The result was that by the end of the year, *MEP*

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13 Based on the Hungarian texts written by Professor Sandor Hajdu, with first drafts of practice books and lesson plans written by Professor Tibor Szalontai, Bessenyei College, Nyiregyhaza and adapted by CIMT

14 It is interesting to note that the *National Numeracy Strategy* has moved substantially on this and now talks about having differentiated tasks for 3 groups, with most pupils in the middle group.

15 So many videos of practice in British schools show children either sitting on the floor or sitting around tables and craning their necks to see the teacher.

had lost many of the original primary schools and one of the main reasons schools gave was the incompatibility of *MEP* with the forthcoming *NNS*.

Another problem was that many schools had mixed-age classes and they felt that the detailed structure of *MEP* was not appropriate. This, of course, is also a problem for mainstream *NNS*. One possible solution stems from our visits to Dutch primary schools where, as in the UK, there is a considerable number of mixed ages classes. Mathematics can be taught interactively to one age group, following the appropriate scheme of work, while the other age group pursues unsupervised individualised work such as reading, art, projects or working at computers, with the reverse situation happening later in the day.

Nonetheless, there were sufficient teachers who, despite finding the implementation of *MEP* very difficult and problematic during the first few weeks, persevered in overcoming problems or found a way to cope with problems out of their control; by the end of the year, these teachers were enthusiastic, delighted and surprised by what they and their pupils had achieved.

From our Year 1 teacher evaluation, the following are typical quotes from teachers who had followed the lesson plans closely:

> *'Having previously taught mathematics to a Year 1 class and comparing the children's ability, understanding and levels of enjoyment to my current Year 1's, I am absolutely amazed at my current class's performance.'*
>
> *'It is not just the higher and middle ability but also the lower achievers who thrive on mental calculations at amazing speed and accuracy. They seem to have developed a quick, agile brain which puts mine to shame.'*

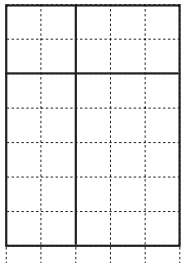
We had initially encouraged extra support to be given to less able children but not to separate them entirely. Teachers could, for example, enlarge the pages from the practice books to make them easier to cope with. Although, at this stage, our comments are based mostly on anecdotal experiences, we are encouraged by the success of keeping the class together, with all pupils gaining. Two observed lessons illustrate this point.

Lesson A In a lesson which centred on the number 14, one of the 8 activities in the lesson required 14 children to be brought out to the front and the class was asked to put them into equal groups. The class suggested two groups of seven and seven groups of two quite quickly but then the teacher (a non-maths specialist) asked, 'How else could they be arranged into equal groups?' After some thought, one of the pupils suggested fourteen groups of one.

This activity, and indeed others in the lesson, gave an opportunity for all pupils to participate, learn and progress, while still providing a challenge which was met by at least one pupil in the class and recognised by the rest. It also helped the teacher, who was not a mathematics expert, to appreciate the underlying foundations of mathematics.

Lesson B This lesson was on shapes and one of the questions in the practice book asked:

How many rectangles can you see in this figure?



Most of the class had no difficulty in finding four rectangles but struggled to make any further progress.

> The only pupil who seemed to see the answer without any difficulty was an SEN pupil who normally struggled with reading, writing and speaking. He recognised the 'double' rectangles very quickly and to the remark from the teacher, 'There is one more to find.' he immediately replied 'the whole shape'.
>
> In other circumstances, this child would not have been exposed to such an activity and although he will undoubtedly struggle with much of the material, he knows that he can succeed where others do not. He was at least given the opportunity, rather than being 'written off' too soon.

Although we undoubtedly had problems, some unforeseen, in implementing *MEP* in partner primary schools, we have also had considerable success and remain confident that implementing strategies used in high performing countries is a better policy than the current compromise which seems to dominate the *NNS* roll-out in most schools.

On the other hand, the *MEP* style of teaching in both primary and secondary does expose weak teachers and the *NNS*, with its differentiated group work, may seem less of a risk for some teachers.

Towards the end of the first year in Primary schools, with the clear message that a number of schools would drop out, we were fortunate to have the opportunity to work with clusters of primary and secondary schools in two of the Education Action Zones, Middlesbrough and Southend. Progress in Year 2, with some of the initial schools and these new clusters, will be reported later in the year.

As part of our evaluation and also for use with the *International Project on Mathematical Attainment*[16], we designed yearly tests to be taken at the start of Y1 and at the end of each year from then on (new questions are added each year but no questions are deleted, so that not only can overall progress be assessed but also progress or difficulties with particular concepts can be pinpointed). Unfortunately, both with the demise of a number of schools and schools being rather lax in implementing the testing in the first year of this primary initiative, we have only limited data.

This situation has been rectified for Year 2, with

- all schools being asked to implement the tests,

as well as the availability of

- international data for comparison
- a national control group
- Key Stage 1 results at the end of Year 2 for the first cohort of pupils.

In two of the primary schools where we were particularly impressed by the enthusiasm and keenness of the teachers to implement *MEP*, we were interested in their *Test 1* results, taken at the end of the first year (unfortunately their pupils had not taken *Test 0* at the beginning of the year).

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16 This is an international comparative project in mathematical attainmnent and full details are on the web at http://www.intermep.org

On a test with 20 marks available, the following results were obtained and for comparison we have added the results of pupils in Singapore and Hungary who took *Test 1* on entry to compulsory education at age 6+. (See *IPMA* (10))

		No. of pupils	Score on *Test 1*	Standard Deviation
School 1		33	14.36	4.72
School 2	Class 1	19	16.84	2.56
	Class 2	18	17.39	1.46
Singapore[17]		1032	15.41	3.84
Hungary[17]		447	11.72	4.91

The success of pupils in Class 2 in School 2, with a very high level of attainment and low standard deviation, gives us an indication of the success of the strategy. The teacher, who readily claimed that she was not a mathematics expert and had not taught this way before, was particularly pleased with the success of the weaker pupils who she felt had gained a lot from whole-class, interactive teaching rather than doing differentiated group work as would have been the case in the past.

We have been both surprised at the success that some teachers (and not necessarily teachers with a charismatic personality but those willing to follow the detailed support of the lesson plans) have had; at times, we felt as if we could have been observing an excellent Hungarian primary mathematics lesson (except that it was in English); on the other hand, it has been disappointing that we have failed to persuade some teachers that it was worth trying and that the *NNS* roll-out has given doubting or worried Heads an opportunity or excuse to pull out.

We look forward with interest to the second year, particularly to the evaluation evidence both in comparison with our English control group and our international 'control', and for Key Stage 1 results. As with the Y7–9 initiative, all resources, including lesson plans, copy masters and practice books, are on the internet, although they have been kept protected until we have sufficient evidence to show their success.

5. Concluding Remarks

The above account is of the first three years of *MEP* but it is an ongoing programme and we seek to learn from the problems and difficulties encountered, as well as to share the successes.

The project is modelled on the methodology:

- ascertain whether there is a problem
- research the problem
- make recommendations
- implement recommendations

17 Note that these pupils are at the start of Year 1, as they begin primary school one year later than in the U.K. but nearly all pupils have had 2 years in Kindergarten.

- obtain feedback and review progress
- evaluate and, where necessary, revise.

The teachers and schools involved are part of the project and neither they nor the project team at CIMT have any financial stakes in the success of this initiative[18].

Given this background, we are pleased to say that we have evidence to show that the *MEP* teaching philosophy works well, even though essentially part of it has been imported from other countries and is being applied in a different environment under different conditions. It is of interest to note that the teaching philosophy bears a strong resemblance to that of *direct instruction* (see (10) and (11)), although there are elements such as the use of homework in secondary schools and the whole-class ethos, which extend this model of teaching and learning.

Successful implementation of *MEP* has not been universal and some teachers and schools are having difficulties in implementation. The research of Joyce and Shavers (12) indicates that direct support in the classroom is a necessary condition to change the practice of some teachers, although it is clear that having the methodology explained and presented through video clips, together with detailed written support, particularly detailed lesson plans in primary, does provide sufficient support for many teachers to affect a radical and successful change in their teaching style in mathematics.

There are, though, some teachers (particularly in secondary) who are less inclined to take risks such as moving completely to an *MEP* style of teaching, with the fear of possibly losing control of the class. Clearly more help is needed to encourage and push such teachers into change and possible actions could be:

a) to encourage more shared observations, although this must be a two-way affair with teachers not feeling threatened by such activities, so it should not be the Head of Mathematics observing and then criticising but for the teachers to observe and comment on the Head of Mathematics; better still, to observe good interactive teaching in other schools;

b) to produce more video sequences of good practice and, when the technology allows it, to disseminate these over the internet;

c) to develop detailed lesson plans for Years 7–9 (as we have done for Years 1–2) so that teachers can at least read about what is expected to happen in the lesson.

There are also other issues which need to be addressed. For example, pupil and teacher absences, for whatever reasons, appear high in this country and as mathematics is a very linear subject, missing even a few lessons can have dramatic consequences on pupils' understanding and progress. We would like to provide some remedies for this and therefore suggest that:

d) all *MEP* material is made interactive on the internet so that
   - lessons can be covered if either pupils or teachers are missing;
   - it can provide home tuition in the cases of long-term absence through illness or school refusal;
   - it would be an excellent way of providing help if a pupil has had difficulties with a particular lesson or concept, or just needs extra practice;

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18 As far as possible, with the aid of advances in the internet, we provide free resources for project schools.

- it would help teachers with mixed age classes, so that one year group could do revision or extension work on their current maths topic on the computer, while the other group is taught interactively by the teacher.

Finally, there is no doubt that we have started a small revolution in the way we teach mathematics; it builds on existing good practice in the UK (see (13)) but also brings in an extra ingredient in the form of interactive teaching as practised in central European countries.

However, we have only a relatively small number of primary and secondary schools involved in *MEP*, and a therefore a very small number of teachers either convinced about or familiar with the strategies. There is perhaps a critical number required before ideas and concepts can spread but we think that the most effective way would be through teacher training. So we suggest that:

e) we provide dedicated *MEP* teacher training routes in secondary mathematics and components of courses for primary training. These resources could be used or
   - inservice training (see b) above),
   - induction for new teachers in *MEP* schools,

   but, above all, to provide new cohorts of teachers who will be ready to implement these teaching strategies with enthusiasm and dedication, knowing that they do enhance mathematics teaching.

The first three years of *MEP* have been very exciting. Despite the many difficulties and set-backs we have always had the feeling, now backed up by data, that this initiative not only contributes to the current initiatives to enhance mathematics teaching in the UK, but could also have a longer term significance in making more believable a time when the UK is proud of its mathematics education and its citizens are confident in their mathematical abilities. We look forward with anticipation to the next three years!

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APPENDIX 1

Kassel Project Recommendations for Mathematics Teaching in the UK

Mathematics Curriculum

1. More systematic treatment, with topics dealt with in depth, rather than jumping around.
2. Clearly specified schemes of work for all abilities.
3. More emphasis on practical numeracy, particularly for pupils who will not continue their mathematical studies beyond 16+.

Mathematics Teaching

1. More emphasis on a clear, precise description of the basic idea or concept being taught.
2. Correct, precise, orderly, spoken and written mathematics used at all times.
3. Limited but effective use of calculators.
4. Encouragement of mental skills and 'learning by heart' important facts and formulae.
5. The use of *relevant* applications for coursework and to motivate new topics.

Teaching Style

1. More whole-class teaching, less individualised work, but a planned combination.
2. Clear objectives and structure to all lessons.
3. Homework used as a crucial and critical component of learning.
4. Individual pupil mistakes used as teaching points with the whole class.
5. Teacher continually monitoring what every pupil is doing and encouraging contributions from as many pupils as possible, including pupils working at the board in front of the class.

Assessment

1. Regular testing, linked to schemes of work.
2. Modified tiering arrangements for GCSE, with all candidates taking 2 papers (for awards up to Grade C), one of which is non-calculator, and an extension paper for higher grades. (Currently this has not been approved by QCA.)
3. *Certificate of Educational Achievement in Mathematics* (WJEC) used for low ability pupils.
4. *GCSE Statistics* encouraged for suitable pupils.

APPENDIX 2

MEP Units of Work for Years 10 and 11

UNIT		ROUTE			
		Standard	*Academic*	*Express*	*Special*
1.	Indices	1.1 – 1.5	1.2 – 1.5, 1.7, 1.8	1.3, 1.5 – 1.8	1.3, 1.5 – 1.8
2.	Formulae	2.1 – 2.4, 2.6	2.1, 2.4 – 2.9	2.4 – 2.11	2.4 – 2.11
3.	Angle Geometry	3.1 – 3.6	3.3 – 3.7	3.5 – 3.10	3.5 – 3.10
4.	Trigonometry	4.1 – 4.6	4.2 – 4.7	4.4 – 4.9	4.5 – 4.9
5.	Probability	5.1 – 5.7	5.2 – 5.9	5.3 – 5.10	5.4 – 5.11
6.	Number System	6.1 – 6.6	6.3 – 6.7	6.5 – 6.9	6.5 – 6.9
7.	Mensuration	7.1 – 7.14	7.4 – 7.16	7.11 – 7.17	7.11 – 7.17
8.	Data Handling	8.1 – 8.6	8.1 – 8.7	8.1, 8.5 – 8.8	8.1, 8.5 – 8.8
9.	Data Analysis	9.1 – 9.4	9.2 – 9.5	9.3 – 9.6	9.4 – 9.6
10.	Equations	10.1 – 10.7	10.2 – 10.8	10.3 – 10.15	10.5 – 10.15
11.	Fractions and Percentages	11.1 – 11.7	11.2 – 11.9	11.4 – 11.9	11.5 – 11.9
12.	Number Patterns and Sequences	12.1 – 12.4	12.2 – 12.4, 12.6	12.3 – 12.6	12.3 – 12.6
13.	Graphs	13.1–13.7	13.2–13.12	13.5–13.12	13.5–13.12
14.	Loci and Transformations	14.1 – 14.10	14.2 – 14.14	14.6 – 14.14	14.6 – 14.14
15.	Variation	15.1 – 15.4	15.2 – 15.6	15.5 – 15.8	15.5 – 15.8
16.	Inequalities	16.1 – 16.3	16.1 – 16.4	16.2 – 16.5	16. 2– 16.5
17.	Using Graphs	-	-	17.1 – 17.4	17.1 – 17.4
18.	3-D Geometry	-	-	18.1 – 18.2	18.1 – 18.2
19.	Vectors	-	-	19.1 – 19.4	19.1 – 19.4

APPENDIX 3

Sample Lesson Report

School: *MEP*/XX **Teacher:** XX **Class:** Y8 (bottom set) **Date:** XX

This was a lively, extremely interactive lesson, taken at a good pace and demonstrating most of the *MEP* recommendations, apart from the review and setting of homework. You had prepared well, emphasised oral and mental work, used practical demonstration to aid understanding and made a conscious effort to involve all pupils. It was good to see that you kept the class together throughout the lesson, especially in written exercises, where there might have been a danger of some pupils speeding ahead and others being stuck at the first question.

The relationship between you and your pupils was excellent, although you sometimes had to think quickly to avoid possible confrontation. On the whole you were successful in keeping potential disruptions in check by exhorting the pupil to do something – answer a question, give an opinion, demonstrate or work at the board – and were quick to praise when deserved Although the class was of low ability and contained a few difficult characters, I felt that most of the pupils progressed.

There are just one or two points I would like you to think about.

- At the beginning of the lesson, you could have used a compass to determine which direction was North and drawn the compass points on a piece of paper or card which could then be pinned to the correct wall (but I do not think that it would really have mattered if you had used the blackboard wall as North – it might have saved some confusion).
- The unit of measurement (degrees) was not emphasised enough in oral and written work.
- The ethnic names on the OHP caused problems for these pupils – you could have replaced them with names of pupils in the class to make the activity more relevant (and then the named pupils could have demonstrated each question).
- It might have been helpful if the pupils had copied down the number of degrees in each turn at the top of the page in their exercise books before doing the exercises, as a reminder.
- Pupils could read out the exercise questions sometimes instead of you (especially the more able pupils who are over-keen to contribute).
- Instead of you reading out the answers for pupils to mark their work, you could ask one or two pupils what they put and then the rest of the class could agree/disagree on the correct response and discuss any mistakes.

Despite these minor criticisms, I thoroughly enjoyed the lesson and your pupils obviously did too. It was very uplifting to see such an enthusiastic and successful implementation of *MEP* recommendations with a class which might have caused problems to a less committed teacher.

APPENDIX 4

School Value-added Data for Subset of Schools

School	*Cohort 1, Y10*	*Cohort 2, Y10*
A	12.99	13.88
B	10.52	5.61
C	8.60	6.36
D	8.59	1.71
E	6.86	3.45
F	5.31	4.20
G	5.23	1.41
H	4.95	1.92
I	1.42	3.62
J	0.94	– 7.39
K	– 0.10	0.93
L	– 0.28	1.88
M	– 0.34	8.24
N	– 0.51	– 1.78
O	– 0.66	– 0.50
P	– 0.69	0.93
Q	– 1.01	3.01
R	– 1.02	2.61
S	– 1.14	6.85
T	– 1.85	0.09
U	– 2.45	– 3.14
V	– 3.20	1.22
W	– 3.20	– 0.63
X	– 3.47	– 9.3
Overall	**1.56**	**2.06**

The value-added score for both cohorts are based on Kassel Project data.

APPENDIX 5

MEP: Secondary Demonstration Project

LESSON CHECKLIST

This is a check list to remind you of the style of teaching which we are recommending. We do not expect you to cover *all* aspects in a single lesson! As a self-assessment exercise, you might like to check both individual lessons and lessons over, for example, a period of a week or two.

- ☐ Seating facilitates easy access teacher–pupil, pupil–board/OHP
- ☐ Mental Maths
  - ☐ Revision of topics covered in previous Units
  - ☐ Revision of main points of Unit already covered
  - ☐ Revision of content covered in previous lesson
- ☐ Homework reviewed
  - ☐ Pupils showing own solutions on board
  - ☐ Teacher stopping pupil at first mistake
  - ☐ Mistakes used as teaching points
- ☐ Spoken maths clear, precise and correct.
- ☐ Maths on B/B or OHS correct, clear, precise and well laid out
  - ☐ B/B instruments used
- ☐ New concept introduced
  - ☐ Interactive discussion
  - ☐ Example worked on board with whole class
  - ☐ Immediate revision of forgotten/misunderstood topics
- ☐ Individual work (exercises/activities)
  - ☐ Teacher continually taking note of what everyone is doing
  - ☐ Class kept together working through exercises
  - ☐ Solutions reviewed with whole class after one or two questions
  - ☐ Mistakes immediately pointed out to whole class
  - ☐ Pupils offer their solutions to class for discussion
- ☐ Whole class on task throughout lesson
- ☐ Whole class progression
- ☐ Humour
- ☐ Enthusiasm
- ☐ Good pace
- ☐ Calculators used
  - ☐ correctly ☐ effectively
- ☐ Homework clearly set (written on B/B or OHS)
  - ☐ extending concepts learned in lesson
  - ☐ link with next lesson
- ☐ Summary of main points at end of lesson

APPENDIX 6

School Value-added Data for Cohort 3, Year 7

	Potential Tests		Combined Year 7 Tests		Combined Year 8 Tests		Value Added		Pupils
Overall	8.03	*3.41*	35.96	*14.34*	44.81	*17.39*	-		5546
A	8.80	*3.15*	41.93	*14.35*	56.08	*16.13*	5.14	*8.53*	206
B	8.19	*3.17*	37.23	*12.71*	50.55	*17.08*	4.68	*10.45*	190
C	8.47	*3.07*	32.48	*13.00*	44.02	*14.28*	3.43	*21.76*	60
D	10.54	*3.06*	49.54	*12.21*	62.28	*13.25*	2.70	*5.26*	39
E	6.95	*3.48*	31.03	*13.50*	41.79	*17.64*	2.36	*8.54*	107
F	8.40	*2.77*	37.93	*12.09*	49.17	*15.49*	2.29	*10.14*	94
G	7.47	*3.37*	35.86	*12.92*	45.88	*15.40*	2.16	*9.63*	192
H	11.60	*2.35*	54.81	*9.41*	67.17	*9.20*	2.11	*6.79*	42
I	8.25	*3.30*	36.32	*13.40*	47.16	*15.20*	2.02	*7.81*	240
J	7.28	*3.00*	32.28	*12.76*	42.84	*16.10*	1.62	*8.02*	120
K	11.26	*2.95*	55.12	*15.53*	65.88	*15.15*	1.57	*5.70*	84
L	9.34	*3.34*	43.33	*15.70*	54.47	*17.75*	1.45	*9.96*	171
M	12.34	*2.60*	61.36	*12.84*	72.25	*11.07*	1.37	*7.88*	56
N	7.58	*3.30*	34.60	*15.32*	44.39	*16.92*	1.23	*8.79*	132
O	7.74	*3.13*	35.80	*12.92*	45.80	*16.11*	1.16	*9.55*	163
P	6.83	*2.92*	28.44	*12.99*	37.98	*15.42*	1.02	*9.72*	178
Q	12.39	*2.58*	54.61	*10.71*	66.24	*11.37*	0.78	*5.88*	59
R	7.54	*3.34*	34.40	*13.61*	44.79	*19.43*	0.45	*9.66*	123
S	8.69	*3.44*	35.48	*14.03*	44.73	*15.88*	-0.06	*8.18*	120
T	6.80	*3.37*	33.01	*12.75*	41.11	*15.98*	-0.18	*10.76*	210
U	8.66	*3.30*	37.68	*12.80*	46.94	*15.83*	-0.19	*7.37*	179
V	7.23	*3.07*	30.76	*12.04*	39.41	*14.83*	-0.26	*7.24*	192
W	8.71	*3.33*	36.31	*11.77*	45.25	*16.43*	-0.58	*11.30*	140
X	5.64	*2.51*	24.15	*8.05*	31.08	*9.92*	-0.73	*8.92*	91
Y	7.95	*3.24*	33.78	*13.81*	42.66	*17.09*	-0.76	*10.05*	155
Z	7.91	*2.95*	35.70	*12.08*	44.32	*13.73*	-0.80	*8.76*	150
AA	7.48	*3.28*	37.03	*12.66*	44.55	*15.98*	-0.93	*13.00*	236
AB	6.08	*3.29*	26.15	*9.42*	32.94	*11.28*	-0.99	*10.89*	86
AC	8.20	*3.69*	35.12	*14.66*	43.16	*17.33*	-1.23	*8.78*	111
AD	8.90	*3.36*	39.72	*13.63*	47.54	*15.75*	-1.76	*7.77*	270
AE	7.93	*3.07*	35.52	*12.52*	41.53	*14.50*	-2.15	*24.63*	91
AF	7.44	*3.20*	32.76	*12.39*	39.91	*15.30*	-2.25	*9.42*	177
AG	8.03	*3.25*	38.01	*14.04*	44.78	*15.95*	-2.43	*7.89*	74
AH	6.55	*3.41*	28.83	*11.55*	35.09	*14.33*	-3.05	*6.62*	76
AI	8.51	*3.12*	36.53	*12.97*	43.17	*16.81*	-3.10	*9.98*	416
AJ	7.52	*3.45*	35.14	*15.38*	40.87	*18.17*	-3.15	*9.25*	100
AK	7.03	*3.21*	27.30	*12.80*	33.19	*15.69*	-3.89	*8.92*	130
AL	6.37	*3.37*	29.99	*13.13*	34.44	*15.48*	-5.07	*8.53*	108
AM	6.41	*3.33*	28.33	*11.49*	32.61	*15.14*	-5.23	*8.70*	70
AN	8.91	*4.08*	31.44	*7.94*	37.72	*11.61*	-5.33	*9.38*	32
AO	8.30	*3.18*	38.82	*13.59*	38.62	*17.01*	-7.92	*27.22*	74

APPENDIX 7

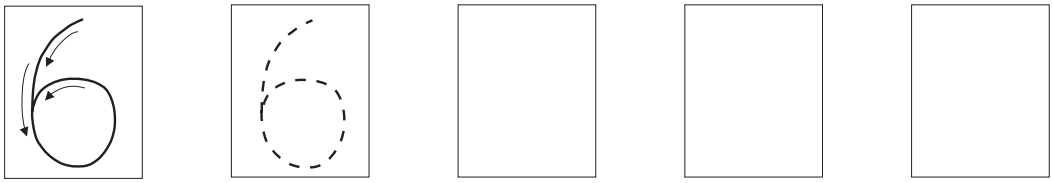
Blueprint for Numeracy

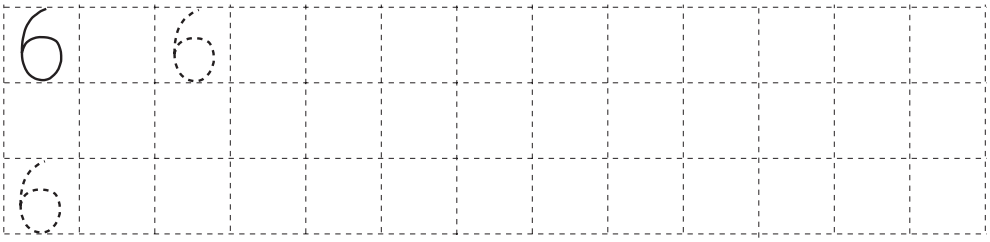
1. Daily Maths lessons early in the morning
2. Lessons begin with 'quick-fire' mental work
3. Key facts learned and practised
4. Exac*t Number Line* displayed in classroom and copies for individual use
5. *Number Cards* used for quick responses
6. Whole-class, interactive teaching with pace and enthusiasm
7. Correct, precise, orderly maths used at all times, both spoken and written
8. Regular informal testing to check progress
9. Calculators used only when pupils have achieved sound number sense
10. Extra practice given when appropriate

APPENDIX 8

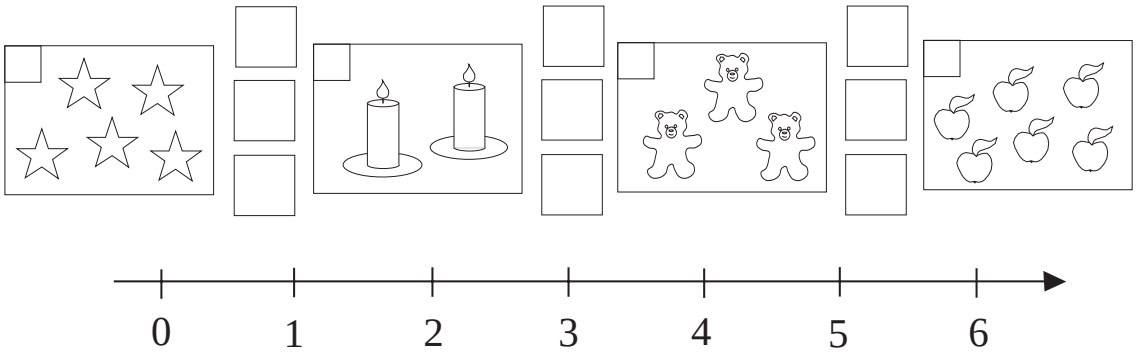
Practice Book Y1a, page 51

1 Continue the pattern.

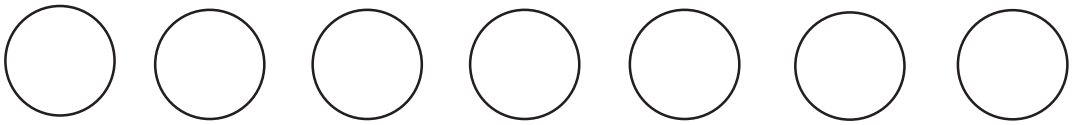




2 Write the correct numbers and signs in the boxes and join the pictures to the number line.



3 (a) Colour in **six** circles.



(b) Tick the second circle from the right.

What is its position from the left? ☐

4 Show the answers by drawing sticks.

| + ||||| = ☐ ||| + ||| = ☐ || + |||| = ☐

APPENDIX 9

Year 1 Lesson Plan 51

Y1	R: Mental counting **C: Writing and using 6, number line** *E: Roman numbers; Cardinal and ordinal numbers*	*Lesson Plan* *51*
Activity		***Notes***
1	**a) Poster 10** Let's look at these pictures. How many animals can you see in each picture? How could we show this using numbers and signs? BB • 6 mice + 1 cat on blackboard (e.g.) 6 + 1 = 7 • 7 little kids + 1 wolf 7 + 1 = 8 • 8 different animals 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 = 8 • 9 ducklings 4 + 4 + 1 = 9 • 10 wolves + 1 pig 10 + 1 = 11 **b) Poster 1** Not counting the toy engine or the hands, how many things can you see in the picture? (6 things: 4 people, a dog and a toy bear) Who can tell us another way to describe 6 things in the picture? ('Not counting the . . . . . .', or 'Counting only the . . . . .') **c) Poster 3** Find animals in this picture which make 6 altogether. (e.g. 4 rabbits and 2 squirrels; 1 tortoise and 5 hedgehogs; 3 frogs, a tortoise and 2 squirrels) *10 min*	(or *Tx1a, page 5*) Whole class activity Discuss stories and different ways to count/write down Agreement, checking Ps show on number line Discussion Agreement, checking Praising Discussion Agreement, checking Praising
2	**Interlude** Finger exercises (action song) *12 min*	Whole class in unison
3	***Tx1a, page 39*** Look at the different ways we can show the number 6. Discuss each. (Show the Roman way to write 6, comparing it with the Roman way to write 5). Hold up 6 fingers (the number card 6). Point to the number 6 on your number line. Which is the next number smaller (greater) than 6? T writes a large 6 on BB, explaining how to do it. Ps draw a 6 in the air, (on their desks, on their neighbour's backs, etc,) ***PbY1a, page 51*** Q.1 Read: *Continue the pattern.* (Let Ps practice on grid sheets first if necessary.) Ask pupils who are doing it correctly to show class on BB. *22 min*	Whole class activity T checking, correcting Whole class in unison Individual work, monitored T helping, correcting Praising only
4	**Interlude** Song or rhyme *24 min*	Whole class in unison
5	***PbY1a, page 51*** Q.2 Read: *Write the correct numbers and signs in the boxes and join the pictures to the number line.* This could be done as a whole class activity at BB. Ask different pupils to come out, one at a time, to do each part. • Write in the correct numbers (or stick on correct number cards) • Write in the correct signs (or stick on correct sign cards) • Join the pictures to the correct points on the number line. Ps copy each stage into their *Pb*s. *30 min*	Drawn on BB or use enlarged picture or OHP. Whole class activity Involve several pupils Discussion Agreement Checking Or individual work, reviewed

Y1		*Lesson Plan 51*
Activity		***Notes***
6	**Neighbouring Numbers** Show me with a number card the number I am describing: • the next number smaller (greater) than 2. (1), (3) • the next number smaller (greater) than 5. (4), (6) • the next number smaller (greater) than 3. (2), (4) *35 min*	Whole class activity At speed Checking, correcting on number line
7	***PbY1a, page 51*** Q.3 Read: *a) Colour in six circles.* *b) Tick the second circle from the right. What is its position from the left?* T writes '6' 'sixth' and '6th' on BB. Ps read them aloud. *40 min*	Individual work Discussion on BB Agreement, checking, correcting
8	***PbY1a, page 51*** Q.4 Read: *Show the answers by drawing sticks.* Review answers with whole class. The ancient Romans used IV instead of 4, V instead of 5 and VI instead of 6. Why do you think they did that? (e.g. fewer sticks used, easier to count for larger numbers) Let's use the Roman way to show the answers: BB: I + IIIII = IIIIII III + III = IIIIII II + IIII = IIIIII Roman: I + V = VI III + III = VI II + IV = VI Hands up those who think the Roman way is easier to read? *45 min*	Individual work, monitored Discussion on BB Discussion Explain on BB: VI = V + I IV = V – I Ps change answer to Roman numerals in *Pb*s.