The teaching of mathematics in schools in England and Wales during the early years of the Schools Council 1964 to 1975

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Abstract

This thesis examines the teaching of mathematics for pupils up to 16 years of age in schools in England and Wales during the early years of the Schools Council, 1964 to 1975.

The thesis is divided into seven chapters. The first is introductory and includes a review of conceptual points and of major primary and secondary sources. The second chapter examines issues in the control of the school curriculum in the first 60 years of the twentieth century and describes the establishment of the Schools Council and its predecessor the Curriculum Study Group.

Chapter three presents the results of an analysis of 176 mathematics text and reference books in use in schools in the early 1960s. The following three chapters provide detailed information about three major projects of the time: the Schools Mathematics Project which generated modern mathematics curriculum content directed initially at pupils in selective secondary schools, the Mathematics for the Majority Project, which concentrated on provision for pupils of average or below average ability, aged 13 to 16 years and the Nuffield Foundation Primary Mathematics Project, which focused on promoting changes in the methodology of teaching the subject.

The major conclusions are that the survey of the books indicates that teachers favoured both traditional content and delivery. However, a number of primary schools were experimenting with new methodologies of teaching, persuaded by the influential recommendations of the Nuffield Project, whilst some secondary schools were introducing new content, nourished by the output of the popular Schools Mathematics Project.

The School Mathematics and Nuffield Projects were important and successful contributors to radical changes in curriculum content and delivery, both immediately and in the long term. Enhanced content, first introduced by the former, forms part of secondary school curricula today, whilst the latter continues to influence current classroom practice.

Contents

List of Abbreviations

ACE	Advisory Centre for Education
AEC	Association of Education Committees
AMA	Assistant Masters Association
APU	Assessment of Performance Unit
ATAM	Association for Teaching Aids in Mathematics
ATM	Association of Teachers of Mathematics
BBC	British Broadcasting Corporation
CEDO	Centre for Educational Development Overseas
CSE	Certificate of Secondary Education
CSG	Curriculum Study Group
CSM	Contemporary School Mathematics
DES	Department of Education & Science
DfEE	Department for Education and Employment
EASMP	East Africa School Mathematics Project
GCE 'O' level	General Certificate of Education, ordinary level
GCE 'A' level	General Certificate of Education, advanced level
HMI	Her Majesty's Inspectorate
HMSO	Her Majesty's Stationery Office
ILEA	Inner London Education Authority
IMA	Institute of Mathematics and its Application
INSET	In-service Training
ITA	Initial Teaching Alphabet
ITA (tv)	Independent Television Authority
LEA	Local Education Authority
MA	Mathematical Association
MMCP	Mathematics for the Majority Continuation Project
MME	Midlands Mathematics Experiment
MMP	Mathematics for the Majority Project
NFER	National Foundation for Educational Research

List of Abbreviations (continued)

NUT	National Union of Teachers
ODA	Overseas Development Administration
OECD	Organisation for Economic Cooperation and Development
OEEC	Organisation for European Economic Cooperation
ORACLE	Observational Research and Classroom Learning Evaluation Programme
RE	Religious Education
Schools Council	Schools Council for the Curriculum and Examinations
SMG	Scottish Mathematics Group
SMILE	School Mathematics Individualised Learning Experiment
SMP	School Mathematics Project
SMSG	School Mathematics Study Group
SRA	Science Research Associates Incorporated (America)
SSEC	Secondary School Examinations Council
TES	*Times Educational Supplement*
UNESCO	United Nations Educational Scientific and Cultural Organisation
2D	Two dimensional
3D	Three dimensional
3Rs	Reading (w)riting (a)rithmetic

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There have been many others, to whom I am indebted, who have worked in different facets of education, both in England and Wales and overseas, and who have given evidence in discussion about the background and substance of curriculum changes in mathematics over the last thirty or forty years of the twentieth century, including Sir William Taylor, Professor Len Marsh, Jim Boucher, Gerry Davis, Bill Dodd, David Feilker, Claire Kinselley, Judy Nicholls, Arthur Razzell, HMI Jim Rose, HMI John Singh, Jo Stephens, David Theobald and Derek Waters.

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Chapter One

INTRODUCTION

The 1960s and 1970s saw many changes in education in England and Wales.This was a time of ferment, of the development of ideas which were often considered revolutionary and which appeared to undermine traditional approaches to teaching and learning at all levels and stages in schools. Projects, focused on a number of subjects and phases, flourished - the more so after the formation of the Schools Council in 1964.

This study concentrates on mathematics education of the 1960s and 1970s for primary and secondary school pupils up to the age of 16. It is set within the context of curriculum change and development which was generated at this time by organisations, projects and individuals. The 'swinging sixties' (and early seventies) saw, on the one hand, the embracing of new freedoms for individuals and, on the other, the questioning of authority and its representatives. This was swiftly followed by a growing focus on standards and accountability, clearly demonstrated in the increasing number of attacks on the way in which the teaching profession carried out its work. In the context of this study these developments were reflected in the encouragement of a child-centred, 'progressive', approach to learning and the beginning of discussions, involving Government, about an appropriate curriculum for schools. These trends, taken together, represented a major challenge both to traditional approaches to teaching and to the professional status of teachers.

The introduction of 'modern mathematics' content in both primary and secondary schools was facilitated by the distribution of materials generated by the new projects of the 1960s. Its origins, however, may be traced to a diverse set of sources, for example, the Bourbakist Movement in France and American mathematicians responding opportunely to the Sputnik event of 1957. Some of the new content, however, was seen by many teachers and some industrialists as undermining customary values and needs in mathematics education. Whilst the project materials enjoyed considerable initial success, a strong reaction began to develop by the end of the 1960s, exemplified by a number of articles in the *Black Papers.* Within a decade, some of the modern mathematics content, such as sets and transformations, originally introduced as free-standing items, were then presented in a manner where their application had a clearer function in aiding the understanding of a mathematical concept.

The purpose of this study is to examine and analyse the work of three projects initiated during the 1960s.The contribution to new knowledge focuses on an assessment of their combined effect on the way in which mathematics was taught and learned in primary and secondary schools in the later1960s and early 1970s. The originality of this investigation is ensured by setting the examination of data about the projects and other concomitant initiatives against a background of baseline information generated by an enquiry into the orientation of textbooks available in schools in the mid 1960s and by a consideration of particular elements of the programme of activities in the first ten years of the life of the Schools Council.The thesis tests whether the application of project activities was as widespread as some of the literature of the time would lead us to believe and assesses whether, in mathematics teaching in primary and secondary schools during this period, continuity or change predominated both in respect of curriculum content and of pedagogy.

Although many of the issues remain contentious, 30 years later it is possible to take a more detached view of the developments of the 1960s and early 1970s. An objective study of the processes, successes and failures of the initiatives of the 1960s may be seen as particularly valuable at a time when schools are subject to government directions over such issues as the Numeracy Hour and whole class teaching.

Indeed, more fundamental critiques have recently occurred. The time devoted to mathematics in schools was and is considerable. Although it seems that teachers, parents and politicians generally support this arrangement, there are others who question the justification of teaching more than a basic utilitarian mathematics curriculum to the majority of the school student population. In the year 2001, this is very much a matter of serious debate, as was illustrated by the controversy generated by the contributions to the two recent Institute of Education publications - *Why Learn Maths?* [1] and *The Maths We Need Now: Demands, deficits and remedies,* [2] and by the keenly argued online debate of the issue on the 24 October 2000, sponsored by *The Guardian.*These arguments give an added dimension to the focus of the study. Elsewhere, in a professorial lecture at the Institute of Education on 2 July 2001 entitled 'Making mathematics reasonable in schools' Professor Hyman Bass, President of the American Mathematical Society and his colleague Professor Deborah Loewenberg Ball, Arthur E Thurran Professor of Mathematical Education at the University of Michigan, cited examples in their research of work with six year olds in which the pupils were given a prescribed selection task to choose two from a finite population of differing coins and then asked to determine the possible range of resultant monetary values. The speakers raised afresh the issue of whether, through intense teacher/class discussion, which is costly in time, pupils' capacity to conjecture and to reason mathematically, an important skill in this subject, can be significantly improved over a short period of time.

Conceptual points

There are a number of conceptual points and key terms to which reference is made in this study. The purpose of this section is to show how they are used.

Progressivism and the reaction

'Progressivism' was a term much in vogue in the late 1960s and 1970s. Simon[3] traced its origins to the 1930s and Selleck[4] to an even earlier period from 1914. In particular Selleck concluded that in the inter-war years the progressives obtained a firm foothold in the training institutions for teachers, including the university departments. "Even if not acted upon, the progressives' views became the most popular views of the training institutions".[5] There is little doubt that a substantial intellectual orthodoxy was established before the Second World War.

One classic definition adopted by the progressives was the oft-quoted extract from the

Hadow Report of 1931, "the curriculum is to be thought of in terms of activity and experience rather than knowledge to be acquired and facts to be stored".[6] As a concept, progressivism embraced a whole range of educational practices, principally concerning methodologies of teaching and learning but also concerning the quality and style of teacher-pupil interaction.

The Plowden Report[7] of 1967, which falls in the middle of the period under consideration in this study, was generally considered to be the high water mark of progressivism in English primary education.[8] Some 68,000 copies of the Report were sold in the first year and 117,000 within three years. The Plowden movement encouraged child-centred education, group work, project activities, the building of open plan classrooms and a more cooperative relationship between teacher and child.[9] In the 1960s there were clear distinctions between those who favoured practices associated with progressivism, those who had no particular view and those who raised dissenting voices. In 1970, Christopher Price MP argued that "the Plowden Report marked the end of an era which relied on an anti-democratic consensus amongst the elite of educational policy makers"[10] - a view which incidentally questioned the attachment of the profession as a whole to progressivism.

By the late 1960s, the word 'progressivism' was frequently used as a pejorative term. This was particularly evident in the contributions of Cox and Dyson, Barzun, Johnson and Bantock to the *Black Papers*.[11] It was suggested that child-centred approaches in the primary school were linked to falling standards. The Bennett Report[12] of 1976 was widely reported as being critical of child-centred approaches to primary school teaching, giving a message that children benefited most from traditional teaching methods and from teaching situations which were carefully structured and teacher dominated.

In this study, the term 'progressive' refers to child-centred education, group work and practical activities in class, the study of 'topics' in school and the local environment, together with emphasis on the teacher acting as a facilitator of pupils' learning rather than assuming a didactic role.

Curriculum

Curriculum is defined as a 'course' and by extension as a 'course of study' and in this latter sense the word is applied to a body of knowledge to be taught. The National Curriculum introduced in this country in 1988 is an example. However, over the last 30 years the word has taken on a wider definition, so that the style and pedagogical methods of teaching the course materials may now be included, the implication being that if a curriculum is to be successfully taught, close attention must be paid to the means by which the materials are delivered. In the context of this study, curriculum refers to both the mathematics content which was taught in classrooms and also to the pedagogy associated with it.

Mathematics.

The word 'mathematics' has such a generalised all embracing meaning today that it is difficult to believe that 50 years ago its use was extremely specialised. Prior to the passing of the 1944 Education Act, elementary schools taught arithmetic, with the addition of some technical drawing, whilst grammar schools taught mathematics consisting of arithmetic, algebra, geometry, trigonometry and statistics. According to the definitions given in the *Longman's Dictionary of the English Language*, 1991,[13] mathematics is:'the science of numbers and their operations, interrelations, combinations, generalizations and abstractions and of space configurations and their structure, measurement, transformations and generalisations'. Arithmetic is 'a branch of mathematics that deals with the operation of addition, multiplication, subtraction and division'. The second is therefore defined as a sub-section of the first.[14]

From about 1964 the term 'mathematics' was increasingly used in primary schools, principally as a result of the impact of the materials of the Nuffield Primary Mathematics Project but also facilitated by the gradual demise of the 11+ examination with its strong requirement for proficiency in the application of arithmetical techniques. The advent of the secondary modern school and the later development of comprehensive secondary education from about 1970, led to the introduction of 'mathematics' into the curricula of these schools, albeit not without pain, since it was soon found that the grammar school type diet was not palatable for many students. New approaches were developed and the major mathematics projects of the 1960s (from which this study draws examples) were responsible for introducing a new approach to the teaching of mathematics in schools, with attempts to make the content more in tune with a wide range of children's abilities and interests.

The term 'modern mathematics', which is still much used, first achieved popularity in the early 1960s. It became a label for a new kind of mathematics content introduced into schools in England and Wales and could be seen as an attempt by mathematicians to reinvigorate the subject with a clientele which on the whole regarded traditional mathematics with suspicion, if not fear, in order to try and improve the mathematical understanding and skills of the population as a whole. The new content, examples of which included the topics of sets, data collection and representation, statistical inference, topology, probability together with some 'applied mathematics' was first seen in the materials published by the Nuffield Primary Mathematics, the School Mathematics and the Mathematics for the Majority projects. To avoid confusion, it is important to distinguish between the different elements of content which were now beginning to be offered at both primary and secondary levels from the mid 1960s. More precisely, 'modern mathematics' content, for example, was represented by a study of sets, Venn diagrams and transformations together with topics which could better be described as in the field of 'applied mathematics', and which were very close to science. Measuring the extension of a spring when weights were added, rolling a ball down a slope of different inclinations and measuring the stopping distance on a level surface, the trajectory of a missile, simple balancing with non-standard and standard weights, are examples of this kind of mathematics, termed at an earlier stage 'mechanics'. Finally a number of topics in traditional mathematics continued to be offered, including in arithmetic.

Undoubtedly, the introduction of modern mathematics content, in its wider definition, into both the primary and secondary sector curricula, encouraged a substantial transition from the limited study of arithmetic and its applications for the majority of the school student population to an examination of a much wider range of topics in the subject, some of which were potentially exciting and intrinsically interesting.

In this study the word 'mathematics' is used as an umbrella term in referring to both 'traditional' and 'modern' content. Where necessary the text will distinguish between different sub-elements of the content.

Secondary sources

The purpose of this study is to examine the impact of mathematics projects and other initiatives of the 1960s and to assess their contribution to change in mathematics teaching. A number of studies deal with the sources of the regeneration of mathematics education whilst some discuss individual projects of the 1960s. Others address the contribution of the professional associations to new developments, focusing on both content and pedagogy. Some have attempted an evaluation of some of the projects, whilst one examined the robustness of the evaluation procedures themselves. None, however, has yet attempted an assessment of the overall impact of the developmental initiatives of the 1960s and early 1970s on mathematics teaching in schools in England and Wales.

In 1984, Barry Cooper described the sources of the regeneration of mathematics education in *On Explaining Change in School Subjects*, edited by Goodson, [15] and in his 1985 publication *Renegotiating Secondary School Mathematics.*[16] He noted the significance of the developments which had been encouraged by the support of the Organisation for Economic Cooperation and Development (OECD), the Organisation for European Economic Cooperation (OEEC) and the United Nations Educational, Scientific, and Cultural Organisation (UNESCO) in the 1960s and 1970s and of a parallel evolution in America which had encouraged the modernisation of mathematics teaching, and which was partially generated by the Sputnik event of 1957. In 1986, Robert Moon published *The New Mathematics Controversy - an International Story.*[17] He noted the influence of the Bourbakist movement, which, in Moon's view, provided a link between the first attempts at academic redefinition of mathematics studies and the later reform of school curriculum. Like Cooper, Moon points up the significance of both the Royaumont Conference of 1959 and the strong supporting role of OECD, OEEC, and particularly of UNESCO, in promoting a modernisation of mathematics curriculum.

Dowling, drawing support from the writing of Ling (1987) and Tammadge (1987), discussed the significance of a series of initiatives generated in the late 1950s by a number of conferences in Europe and by the School Mathematics Study Group (SMSG) in America which emphasised an axiomatic and highly rigorous approach to the study of 'modern mathematics', ('new math' in America), and points to a measure of success by these initiatives in persuading teachers of the need to change their practice.[18]

Some authors focused on individual mathematics projects of the 1960s.This study clearly concentrates on an historical approach, whereas Cooper, a former teacher of School Mathematics Project (SMP) mathematics, used a sociological approach in examining the origins of the redefinition of English secondary school mathematics which took place in the early 1960s, with special reference to SMP. For comparative reasons he developed an interest in the Midlands Mathematical Experiment (MME), a rival to SMP in this period. He concluded that changes in mathematics teaching in England and Wales were largely dependent on the selective status of some schools (and their special links with universities) and the teachers who were employed there, and that the proposals for redefinition of secondary school mathematics were orientated to the demands of the powerful providers of resources, notably from industry. In Cooper's view, the new SMP syllabuses and textbooks could be seen as a compromise between the demands of the modern algebraists, who, in preparation for the GCE 'O' level examination, principally favoured the study of, for example, set theory and symbolism, number bases, transformational geometry and probability theory, and the alliance of applied mathematicians and employers who favoured a more practical approach involving the study of, for instance, statistics, and linear programming with a focus on 'models' of situations.[19] His research led to the award of a D.Phil. degree from the University of Sussex in 1982.[20]

Moon undertook a study of curriculum development in five European countries, with special reference to primary school mathematics, which led to the award of a D.Phil. degree from the University of Sussex in 1985.[21] His study provided a yardstick by which accounts of recent curriculum history could be reviewed. Within the context of this study however, Moon's appraisal of initiatives in England and Wales during the 1960s and 1970s, in chapter six, which concentrated heavily on the history and development of the Nuffield Primary Mathematics Project, is of considerable significance.

In a journal article in 1978,[22] A G Howson gave an overview of changes in mathematics education since the late 1950s and argued that the beginnings of reform in mathematics teaching were seen in the output of the Schools Mathematics and Contemporary School Mathematics projects, although applied in selective secondary schools. He differentiated between the aim of SMP in attempting to change the content of courses and that of the Nuffield Primary Mathematics Project in trying to modify both content and the methodology of delivery. He commented that the dissemination of the latter's ideas was hampered both by the absence of pupil materials and by the lack of informed teachers. Howson took a similar view of the implementation of the Mathematics for the Majority Project and believed the impact of the Teachers' guides to be negligible. He identified a significant change in responsibility for mathematics curriculum development in that by 1975 the old 'top-down' model of materials being centrally produced by specialists and then disseminated to schools was being abandoned and replaced by locally produced materials written by teacher groups, as in the case of the products of the Mathematics for the Majority Continuation Project, the Kent Mathematics Project and the School Mathematics Individualised Learning Experiment (SMILE).

In-service training is an important feature of any strategy to improve the teaching of a subject and this study endeavours to assess the effectiveness of programmes of training for teachers which were offered by some mathematics projects of the 1960s. A number of authors have made pertinent observations in this context, including HMI Edith Biggs who, beginning in 1976, undertook action research leading to a case study, as part of her study towards a Ph.D. degree at the Institute of Education, University of London.[23] Her aim was to help teachers broaden their approach to the teaching of mathematics and to plan activities which would provide opportunities for children's discussion and the creation of mathematical concepts. Her findings illustrated the range of activities required to secure change in the teaching of mathematics, for example by stressing the need for in-class support for teachers following in-service training and the need for headteachers, as facilitators, to attend training sessions for mathematics coordinators at infant, junior and middle school level.

R M Bond[24] reported on the enthusiastic response by teachers to the task of producing effective in-service training programmes in mathematics and to the idea of establishing a professional centre for mathematics education in Leicestershire. J Melrose [25] reviewed the effectiveness of the Mathematical Association's Diploma in Mathematical Education, initiated in 1978, in relation to its use as an in-service training tool for primary school teachers. P K Armstrong [26] addressed strategies and techniques related to the provision of in-service training for special groups of teachers and targeted those with limited qualifications and experience in the subject.

Evaluation of an initiative is a key feature in determining a measure of its success. It is clear from the literature that objectivity of approach was not as significant a requirement in the 1960s as it is in the year 2001. No one was willing, ultimately, to hazard an assessment of success of a project. In *A Review of Research in Mathematics Education, Part C,* [27] published in 1983 by the NFER, Howson described a number of evaluation studies, most notably that of the *Nuffield Primary Education Project* by Hewton in 1975[28] and those published by the Schools Council in 1973 - *Evaluation in Curriculum Development: Twelve Case Studies.*[29] The former was extremely comprehensive in scope and addressed a range of issues including the form of the project implementation, costs and resource management, and the unfulfilled plans for its evaluation. One of the case studies in the latter publication reviewed the Mathematics for the Majority Project, although it concentrated more on analysis of data concerning the experience and attitudes of teachers and pupils than on an attempt to assess the effectiveness of the Project.The evaluation procedures described in the 12 studies were roundly condemned by Munro in his paper in the *Journal of Curriculum Studies* in 1973,[30] and insofar as the Mathematics for the Majority Project was concerned, the value of its evaluation was limited to a descriptive account of the factors influencing the teaching of the materials. Howson, Kietel and Kilpatrick in *Curriculum Developments in Mathematics*[31] argued that the elaborate evaluation scheme for drafting, testing and rewriting the pilot stage materials of the MMP created considerable limitations for the efficient dissemination of the substantive versions.

The contribution of the professional mathematics associations to curriculum development was significant. Cooper, [32] in 1982, noted that of the Association for Teaching Aids in Mathematics (ATAM) and that of the Mathematical Association (MA) to the movement for change. Also in 1982, Howson, in *A History of Mathematics Education in England*[33] referred to the role of the Association for Teaching Aids in Mathematics, - of which Caleb Gattegno, a distinguished lecturer at the Institute of Education University of London in the 1950s, was the first Director - in promoting improvements in the content and delivery of primary stage mathematics. He made reference to the strong contribution of Elizabeth Williams and to the three reports of the Mathematical Association published in 1955, 1959 and 1963 with which she was concerned. All were important as exemplars of new thinking at this time and Howson assessed their contribution to change. The first, entitled *The Teaching of Mathematics in Primary Schools* [34] (1955) had considerable impact and was influenced by the reforming ideas of Caleb Gattegno. In a second report, *Mathematics in Secondary Modern Schools*[35] (1959), Cyril Hope, an able mathematician based at Worcester College of Education, made an important proposal to widen the breadth of mathematical content beyond arithmetic and to develop the themes of 'utility' and reality' which had been discussed within the Mathematical Association 50 years before. In putting forward a case for a mathematics curriculum suitable for ' B and C stream pupils', he showed that his thinking was along the same lines as Philip Floyd at Exeter who was responsible for initiating the Mathematics for the Majority Project, reviewed elsewhere in this study.

The third of the Reports, entitled *The Supply and Training of Teachers of Mathematics*[36] (1963), drew attention to the negative effects of the then current shortage of mathematics teachers which were to have the inevitable result that pupils would be taught by non-specialists.

The Mathematical Association published a further Report, *Mathematics 11 to 16*,[37] in 1974. The writing team included Elizabeth Williams and Geoffrey Matthews who became Director of the Nuffield Primary Mathematics project in 1964.The Report represented a move away from a more conservative approach to mathematics teaching and devoted some space to methodologies of teaching and learning and to the utilisation of ideas and materials from projects (both primary and secondary) as vehicles for developing mathematical understanding.

Although principally focusing on the history of the Mathematical Association, the publication by Michael Price entitled *Mathematics for the Multitude: A History of the Mathematical Association*[38] (1994) illuminated a substantial range of developments in mathematics education in the period addressed by this study, although not in any great detail. Price noted, for example, that the Association's view on the implementation of primary mathematics work had shifted from teaching to learning following the appointment to the Teaching Sub-Committee of Miss Adams and Caleb Gattegno. The Association contributed to a discussion about in-service training in mathematics convened by the Royal Society in 1965 and joined with the Institute of Mathematics and its Applications (IMA) to form a Joint Committee for Mathematical Education under the auspices of the Royal Society. It published, in 1968, a short but useful account of projects being developed in British secondary schools.[39] Price noted the Mathematical Association's input to the Royaumont and other conferences and the involvement of the Association's members in the writing and publication of materials by OECD, OEEC and UNESCO.

The contributions of the Mathematical Association (MA), the Association for Teaching Aids in Mathematics (ATAM) and the Association of Teachers of Mathematics (ATM) forms part of a comprehensive review, by Clare Tickly, of factors which influenced developments in school mathematics, and which was published in October 2000 under the title *Continuity and change in school mathematics since 1945*.[40] Studies of these

Primary sources

The principal primary sources used in this study may be divided into eight categories:

Research and publications of the OEEC, the ATM, UNESCO and the Assistant Masters Association (AMA).

Three major mathematics projects initiated in the 1960s: the School Mathematics Project, the Mathematics for the Majority Project and the Nuffield Primary Mathematics Project.

The publications of the Schools Council related to mathematics education from 1964 to 1975.

The conclusions of Professor Piaget related to conceptual development and mathematical understanding and their applications in colleges and schools.

A collection of some 50 individual mathematics textbooks, or series of textbooks, and reference books, in use in primary and secondary schools in the 1960s and 1970s.

The *Plowden Report.*

Reactions to the 'modern mathematics' approach by the media, publishers and other bodies.

Interviews with some 35 individuals who were professionally engaged in the education field, or were students at school, in the 1960s and1970s

A key point in the attempts to modernise mathematics curriculum was identified when the Bourbakist Movement put forward a number of proposals for reform, with an emphasis on pure mathematics, at the Royaumont Conference in 1959, funded by the Organisation for European Economic Cooperation (OEEC). These were disseminated alongside the pioneering American efforts of the School Mathematics Study Group (SMSG). Conference discussions led to a major collaboration which resulted in the publication by the OEEC in 1961 of *Synopses for Modern Secondary School Mathematics,* [46] which set out proposals for a revised curriculum. In the same year the OEEC published *New Thinking in School Mathematics*[47] which reported, in part one, on the Royaumont Conference and the controversy over the suggested removal of Euclidian geometry from the curriculum. This issue was important in that it epitomised the division between those who supported a new approach to curriculum reform and those who largely wished to retain the traditional. *New Thinking in School Mathematics* put forward the case for reform in mathematics teaching and argued that the changes in cultural, industrial and economic patterns in many countries called for a basic change in educational patterns. Part two reviewed issues such as the retraining of teachers, learning materials and examinations.

In 1964, a group of members of the Association for the Teaching of Mathematics (ATM), inspired by the Royaumont Conference, produced *Some Lessons in Mathematics,* [48] with a foreword by Bryan Thwaites, setting out ideas for a new approach in curriculum.

UNESCO, Paris, became the principal international source of support for the reform movement in mathematics curriculum. It published four volumes under the general title of *New Trends in Mathematics Teaching,* [49] in 1966, 1970, 1972 and 1979 respectively. These were significant in charting the different emphases in endeavours to reform mathematics teaching over these years. In the 1972 publication, for example, attention was drawn to the changes which had already taken place in primary schools with pupils being exposed to basic algebra and geometry, binary operations, sets, mappings and probability, with an emphasis on active investigatory methods and on links with other subjects. The 1979 edition reviewed and differentiated between the work of the initial large scale projects, centrally directed, and local and individual projects working at the periphery, which, by this time, were becoming more popular. The problem of evaluation of project activity was also discussed; it was significant that the authors took the view that most evaluation programmes had been inadequate.[50]

In 1973, the Assistant Masters Association (AMA) published *The Teaching of Mathematics in Secondary Schools.*[51] The coverage was comprehensive, describing the beginning of the movement for change in mathematics curriculum articulated at the Royaumant Conference before focusing on developments in England and Wales which subsequently led to the implementation of the CSM, MME and SMP projects. One chapter reviewed the options in number, algebra, geometry and calculus which were available as new course material. A section on mathematics for the less able followed, whilst the link between mathematics and other subjects was explored. A cautionary note was struck in remarking that children cannot 'discover' everything in mathematics and that opportunities for consolidation and practice must be provided. The book reflected the contemporary thinking of mathematics teachers about the limitations of devising a fresh approach to the teaching of the subject.

UNESCO, the OEEC and the professional associations were important in providing a focus for discussion of ideas related to curriculum renewal at this time. In the context of this study, the literature provides a useful indicator of the development of thinking over the 20 year period from 1959 to 1979.

Of major importance are the materials produced by three major projects of the 1960s concerned with mathematics teaching and learning which constituted exemplars of vehicles of potential change. The Nuffield Primary Mathematics Project, sponsored, although not financially supported, by the Schools Council, focused principally on mathematics in primary schools, although some of its work targeted the lower secondary stage of education. The Mathematics for the Majority Project (MMP), supported by the Schools Council, targeted the needs of pupils in the last two years of secondary school who were deemed to be of average and below average ability, whilst the Schools Mathematics Project (SMP) served, initially, the needs of children in selective secondary schools who would be preparing for the GCE 'O' level examinations in mathematics. These projects generated new content and methodologies of teaching and learning in mathematics - they were the bright stars of the developmental firmament of the time and preached a gospel which was vastly different from that which obtained prior to 1960. They were of considerable significance for change in mathematics teaching in England and Wales in the 1960s and 1970s. They are reviewed, in depth, elsewhere in this study.

The Schools Council *Curriculum Bulletin Number 1: Mathematics in Primary Schools,*[52] written by HMI Edith Biggs and published in 1965, is regarded as an important marker in the debate about a new approach to mathematics teaching in primary schools; this volume, and the ideas it contained for expanding curriculum content and changing methodologies of teaching, powerfully informed the in-service training of many teachers in the years after 1965.

The issue of achieving worthwhile evaluation has already been raised in this chapter. A Schools Council initiative in 1965 planned an evaluation of the Nuffield Primary Mathematics Project and appointed an HMI to organise it.[53] Consequent upon his early resignation, this evaluation did not proceed.[54] Despite this setback, the Schools Council's *Field Report Number Four,* [55] reflected its continuing interest. An evaluatory study which would illustrate successes and weaknesses in different approaches to mathematics teaching began in 1972, based at Reading University School of Education. *Schools Council Primary Mathematics Project: The First Six Months, 1973, Pilot Study Results,* with a sub-title *What's going on in Primary Mathematics?*,[56] was published in 1973, as was a separate study, *Evaluation in curriculum development: Twelve Case Studies: papers from the School Council's project evaluators on aspects of their work.*[57] A reading of these works indicates that techniques of evaluation in the 1960s and 1970s were unsatisfactory. Although useful in providing background information and some data, their principal value must be in the encouragement of a more objective approach to this topic.

The conclusions of Professor Jean Piaget and his suggestion that all individuals pass through four intellectually developmental stages, created considerable interest in the 1960s and 1970s. Piaget wrote a number of books in the context of mathematics, which were translated from French into English, for example, *The Child's Conception of Number*[58] and *The Child's Conception of Geometry.*[59] Interest in Piaget's conclusions was such that many authors wrote commentaries on his work, some in the form of a short booklet, some as longer texts. Keith Lovell's *The Growth of Basic Mathematical and Scientific Concepts,* [60] (1961), is an example of the latter. Ten years later Lovell returned to the topic with the publication of another book - clearly written for the American market - *The Growth of Understanding in mathematics, Kindergarten through Grade Three.*[61]

New Light on Children's ideas of Number: The work of Professor Piaget, [62] by Nathan

Isaacs, was an example of a booklet which was regularly found on reading lists for college of education students and for in-service training courses in the 1960s and 1970s. Such lists are useful primary sources and an example will be found as Appendix A to this study. *New Light on Children's ideas of Number* was sufficiently popular to be reprinted eight times, the ninth impression in 1972. Isaacs' book *The Growth of Understanding in the Young Child: a brief Introduction to Piaget's work,* [63] published in 1961, was reprinted seven times, the eighth impression in 1969. A similar explanatory volume authored by Evelyn Lawrence, T R Theakston and Nathan Isaacs was issued by the National Froebel Foundation in 1955 and entitled *Some aspects of Piaget's work.*[64] There is little doubt that the majority of students and teachers did not read either the original or the translated versions of Piaget's works, relying instead on the explanatory texts to gain an understanding of his conclusions. Most readers therefore - teachers, lecturers and students in training - acquired a simplified and possibly inaccurate version of what Piaget had written. Supporters of the new pedagogy of teaching, especially those employed in the colleges of education, drew heavily on these interpretations of his conclusions, some of which, in later years, were found to be unsustainable in rigorous argument. Some of the educationalists interviewed as part of this study were working in colleges of education in the 1960s and 1970s and their first hand evidence on the effectiveness of the approaches which were then being advocated, in the light of Piaget's conclusions, is a useful primary source.

The Plowden Report, *Children and their Primary Schools,* [65] published in 1967, devoted a subsection to a short account of current and former practice in mathematics teaching, reviewed some contemporary projects and made suggestions for more effective mathematics teaching in the future. Plowden quite clearly supported the notion of putting children in relatively unstructured situations by giving them opportunities to discover relationships and develop a conceptual understanding, but a major deficit was that it said little or nothing about the need, if it existed, for children to undergo a systematic programme of practice exercises to formalise the treatment of a topic. Plowden paid little heed to the problem of a possible decline in accuracy and computational skills, but was upbeat about the positive effects of the new approaches. What was lacking in the

Plowden Report was any reference to a definitive strategy to deliver a worthwhile and cohesive mathematics curriculum within the context of the new approaches which were being advocated.

A range of some 50 individual mathematics books or series of books, in total amounting to 176 volumes, which were in use in primary and secondary schools in the 1960s and the 1970s is reviewed in this study. The survey, although not exhaustive, gives a strong indication of the orientation of books popularly used in schools at this time, both in regard to content and methodology of teaching.

A clear reaction both to new mathematics content and to new suggested methodologies of teaching the subject had emerged by the early 1970s. For example, Morris Kline, Professor of Mathematics at New York University, published *Why Johnny Can't Add: The Failure of the New Math,* [66] which was a rebuttal of modern approaches to content. He argued strongly that whilst there was nothing intrinsically wrong with set theory - in fact its study was necessary at undergraduate and graduate levels - it was unnecessary for elementary and high school students to devote time to these activities.

Kline argued that there were deeper reasons for the changes which had taken place. One hundred years before, mathematics was used as a tool of science, but more recently the link had been broken, resulting in a narrowing of mathematical specialisation leading to its functioning independent of the physical world. He felt that the proper way forward was to return to a useful and applicable curriculum in mathematics but to include new content if it could be sustained. He was critical of pure mathematicians who had little pedagogical insight and who had imposed a new curriculum on teachers who did not have the time or the knowledge to acquire it for themselves.

In England, Stuart Fromme had published *Why Tommy isn't Learning*[67] in 1970. In a wide ranging condemnation of 'modern methods' he targeted what he considered the resultant decline in pupils' arithmetical competence. Fromme argued that the new methodologies of learning including discovery work, would militate against an ordered sequence of learning for pupils and that of all the subjects in the timetable, mathematics should be securely based on a firm structure of knowledge and intellectual skills acquired through systematic teaching.

The argument about the practical use of new content, was the subject of a feature in the *Times Educational Supplement*, in an edition of 1 February 1974.[68] A range of individuals representing the manufacturing, shipbuilding and engineering industries expressed concern about the absence in the new materials of training opportunities for students for conventional tasks of drawing plans and developmental work.

One of the strongest reactions to the new approaches to teaching mathematics was signalled through the publication of the *Black Papers*. These suggested that child-centred education in the primary school was linked to falling standards. The second *Black Paper*[69] published in 1969, focused on primary education and did much to promote the debate about appropriate curricula (including core curricula) and its delivery in the next two decades, ultimately facilitating the laying of foundations for the 1988 National Curriculum

The powerful nature of the reactionary forces provided an effective counterbalance to the ideas flowing from the initiatives of the mid 1960s and early 1970s, clearly limiting their impact on teachers and encouraging the maintenance of a traditional approach to mathematics content and teaching.

Oral evidence was gathered from some 35 individuals who were either professionally occupied in a broad spectrum of education activities or were school students in the 1960s and 1970s. This evidence has not been used in any systematic quantitative way but rather to enhance comment within each chapter of the study. Except in this chapter, observations will be simply described as coming either from 'educators' or from 'students' respectively. A simple categorisation showing the role of members of the group in the 1960s and 1970s, and the present role, or the most recent if retired, is given as Appendix B.

Additionally the author's experience as a teacher in the late 1950s, as a member of a college of education staff in the 1960s, ultimately as Deputy Principal of Battersea College of Education, as a specialist in primary stage mathematics employed in the Malaysian Federal Inspectorate of Schools by the British Council and later still as Adviser and Chief Inspector of an outer London Borough, was drawn upon in compiling this study.

Arrangement of the Thesis

Chapter two gives an account of the formation of the Schools Council and its immediate predecessor the Curriculum Study Group. The account is set against a background of the history of control of curriculum over the first 60 years of the twentieth century, principally to show how and when teachers have been given the opportunity to determine content and methodology of teaching and how they have used that opportunity when it became available. In this particular context attention is given to the uptake by teachers of the outputs of the Schools Council in relation to mathematics teaching and the quality of that uptake.

Chapter three of the thesis analyses an extensive selection of mathematics text and reference books in use in primary and secondary schools in the 1960s and 1970s. The survey illustrates how the more traditional mathematics textbooks, with their emphasis on practice exercises and problems, were gradually beginning to lose ground over the period to the newer books both in relation to content (by including in some cases 'modern' or 'new' mathematics material) and in relation to methodology of its presentation, resulting in a vastly changed style and in a much more attractive appearance. The base line established by this survey indicated that, in the early to mid 1960s, most teachers supported traditional content delivered in a traditional manner. However it is also apparent that, over the period, they were increasingly exposed to new content and to suggestions for a new approach to teaching.

Chapters four, five and six respectively review the work of three important mathematics projects of the 1960s and 1970s, all of which had some relationship, albeit in the first case somewhat tenuous, to the Schools Council: firstly the School Mathematics Project, secondly the Mathematics for the Majority Project and thirdly the Nuffield Primary Mathematics Project. All three were highly significant in that, each in its own way, was in the vanguard of attempts to improve mathematics curriculum, both in terms of content and in terms of its presentation to pupils.

Chapter seven provides an overall review of the evidence examined in the preceding chapters. It attempts to determine whether the developmental activities in the 1960s and 1970s did in fact substantially change the teaching and learning of mathematics in primary and secondary schools in England and Wales and whether there were concomitant changes in the professional life and status of teachers as a consequence of these initiatives.

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Chapter Two

CURRICULUM CONTROL AND THE FORMATION OF THE SCHOOLS COUNCIL

This chapter is divided into three sections. The first examines four issues - the content of the curriculum, who controls and directs it, how such control and direction is exercised and the purpose of that control. The second section briefly reviews, within the context of these issues, curriculum in the first half of the twentieth century, whilst the third provides a short account of the formation of the Schools Council in 1964, the priorities it established for curriculum development and its subsequent history. A conclusion follows. The overall purpose is to set the curriculum developments of the 1960s and early 1970s, and especially the projects in the field of mathematics, in the context of the history of curriculum control and direction in the twentieth century and particularly in the period of freedom for teachers to develop their own curricula in the post second world war era, leading up to the formation of the Schools Council

Curriculum

Denis Lawton has suggested that the content of a school curriculum may be seen as a selection of knowledge, values and attitudes from a society's culture which it is considered important to transmit to the next generation.[1] The curriculum can mean the formal courses and classes offered to students, but it also embraces those elements which are defined as part of the hidden curriculum. Two questions arise immediately: who controls the selection of content, and secondly, is the same curriculum to be offered to pupils and young people universally. Inevitably the choice of content of the curriculum and to whom it is offered is never value free. It was and is subject to some form of control shaped by an individual, or by a committee or by government direction. At the present time, the stress on the acquisition of Information Technology skills by pupils in schools is an example of shaping the content of curriculum, and its purpose is justified by the need to raise technological awareness and facility for the generation which will enter the employment market in the next few years. Specific government funded in-service training for teachers to facilitate the acquisition of these skills by pupils is an example of how control and direction of curriculum is exercised.

Curriculum content may become a means of challenging, rather than promoting transmission of knowledge and values, and may become an area of dispute between those who wish to preserve, and those who wish to change or modify, certain traditional views of society. The question of how British history should be approached in the National Curriculum provides a good example of disagreement, when, during the period of its initiation, Secretary of State Kenneth Baker was clear that he wished to promote a curriculum which championed Britain's past achievements and glories, whereas others wanted to stress, within this context, the histories and rights of other nations. The government directive that religious education in schools in England and Wales shall reflect a fundamentally Christian approach, despite the fact that a large proportion of the pupil population of many schools, particularly in big cities and towns, adheres to other faiths, is an example of control and direction by authority which fails to take sufficient account of cultural differences.

There are a number of forces which can control and direct curriculum, sometimes in a positive and enlightened manner, sometimes in a negative and restrictive way. In the 20 year period after the passing of the 1944 Education Act, it was widely believed that headteachers and teachers held this responsibility. Whilst accepting that his view is necessarily subjective, the author believes, having visited many schools in the 1950s and 1960s, that, in the vast majority of cases, headteachers and teachers offered a sound, although occasionally uninspiring, basic curriculum to pupils. The acceptance of this responsibility by teachers was encouraged by the wish of politicians, both national and local, not to become involved in matters of curriculum - indeed the famous quotation of Minister George Tomlinson represented a widely held view, when he said, in introducing the Ministry's 1950 Report: '..The Department of Education has been zealous for the freedom of schools and teachers..'[2]. This approach is in marked contrast to the present situation, in which, through the imposition of the National Curriculum, government controls and directs curriculum in schools, legitimized through an Act of Parliament.

The purpose of control and direction of curriculum can be seen as facilitating the efficient use of resources. An example of the latter is seen as a product of the Newcastle Commission Report of 1861, where concern was expressed at the unsatisfactory and wasteful features of the existing system of elementary education. Robert Lowe, Vice President of the Committee of the Privy Council on Education, was responsible for introducing the Revised Code of 1862 which set out conditions under which the financial grant was to be paid to elementary schools in relation to the teaching of the 'basic' subjects, essentially focusing on the three Rs, and relying on examination and inspection for its implementation.[3] This was payment by results, based on a market economy, in which control and direction of curriculum was exercised by government. Although the teaching of other subjects was not precluded under the Revised Code, a by-product of its introduction was an inevitable concentration on the three Rs and the increased incidence of what was described as mechanical teaching.[4] It is thus apparent that any form of assessment or testing can be seen as a form of curriculum control.

On the other hand the energetic approaches to curriculum improvement of some of the large School Boards of the late nineteenth century, in, for example, London, Birmingham and the north of England, represented a more positive and creative feature of control and direction through the introduction of opportunities to learn music, cookery and physical education[5] and through provision for the needs of physically and mentally handicapped children. The purpose of these improvements was to make a richer curriculum available to pupils, acknowledging that a curriculum needed to consist of more than a diet of basic skills.

An example of more deliberate control procedure in the nineteenth century, related to a specific subject curriculum, was generated by individuals who regarded class interests as very important. A view was taken that it was necessary to match the curriculum material to the mentality of different social classes. Facts and stimulation were to be the appropriate diet for the lower orders and principles, manipulation and abstraction were the requirement for the upper classes.[6] An experimental approach to science learning defined as 'the science of common things' was developed by Richard Dawes at King's Somborne in Hampshire from 1842.[7] It gained official acceptance by the Committee of the Council on Education, following its wider success in the 1850s. Its programme was differentiated in that it stressed the study of the 'concrete' for the lower orders (showing some similarity to the material offered in the 5-13 Science scheme which was produced in England and Wales some 25 to 30 years ago), and for the higher orders, conjectural science.[8] This experiment was curtailed because there was a fear that giving knowledge of the resources of science to the lower classes would effectively give them power.[9] The concern to maintain the social order for the benefit of the upper classes was illustrated by a remark attributed to A.C.Tait, later Archbishop of Canterbury, who observed, in 1854, that the experiment in science teaching was making such good progress that the higher orders were being left behind, which could result in the son of a labourer possessing more knowledge than the son of a squire - with a consequent threat of disturbance to the social order.[10] In 1860, Lord Wrottesley's Parliamentary Committee of the British Association for the Advancement of Science observed, in relation to the experiment, that 'the social hierarchy was under threat because there was not a corresponding development in thinking skills for the higher orders' [11] and soon afterwards science was removed from the elementary curriculum, the purpose being the wish to nullify the possibility of this result. When it reappeared some 20 years later, it was very different from Richard Dawes' science of common things. A watered down version of pure laboratory science had become accepted as an appropriate course of study.[12]

Curriculum in the first half of the twentieth century

Following the decline of the principle of payment by results in the last decade of the nineteenth century, the Elementary Code of 1900 and the Day School Code of 1902 set out a list of subjects which elementary schools were expected 'as a rule' to teach: English, arithmetic, geography, history, singing, physical education, drawing for boys and needlework for girls, with additionally, and if practicable, the study of one or more subjects such as science, French and algebra.[13] For the first time, curriculum content was thus defined, although there was to be no examination requirement, the school being subject to general inspection only. The 1904 Elementary Code went further in encouraging schools to form and strengthen character, to develop the intelligence of pupils and to fit them, practically as well as intellectually, for work. There was some provision for the transfer of able and gifted pupils to the new secondary school, although this was counted as a subsidiary objective. However, despite the high-flown sentiments expressed in the 1904 Code, one view of its reading reinforces the impression that an elementary curriculum, with elementary standards of attainment, to which this large population of pupils up to the age of 12 would be exposed, was intended and expected.[14] An alternative view, that teachers were now given a means for effecting a more liberal interpretation of the teaching of this curriculum, is supported by the publication in 1905 of the first *Handbook of Suggestions for the Consideration of Teachers and others concerned with the Work of the Public Elementary Schools,* [15] subsequently revised and reissued on several occasions over the next 40 years. Both subject content and methodology of teaching and organisation were addressed. The 1927 *Handbook,* [16] for example, listed the following as main subjects: educational management, primary education, curriculum, teachers, hygiene, school organisation, music education, lessons, school children and the 1920s. Two later editions, in 1928[17] and 1933,[18] specifically addressed a number of health issues, such as disorders, infectious diseases, self - cure skills and child health, in addition to routine topics such as primary education and educational management. The 1937 *Handbook* [19] focused on nursery schools, infant schools, secondary education, the League of Nations and the 1930s, whilst the 1944 publication[20] addressed the same subjects as the 1927 edition, (above) but the final subject focused on the 1940s instead of the 1920s.

Elementary schools ceased to exist after 1944 and hence the original title became obsolete. The 1959 Handbook was entitled *Primary Education: Suggestions for the consideration of teachers and others concerned with the work of Primary Schools*[21] and contained chapters which addressed the teaching and learning of religion, physical education, language, mathematics, art and craft, and needlework, handwriting, music, history, geography, and natural history.

In the context of the elementary school, Government conceded control of the curriculum to the local authorities and the teachers in the 1926 code. John White, however, suggested that the motivation of Lord Eustace Percy, the President of the Board of Education, for abandoning control of the curriculum by means of regulation, was not a desire to give teachers freedom, but the more negative reason of a fear that, in the year of a general strike, an incoming Labour government might use the powers which existed in the regulations to control the curriculum in an explicitly socialist way.[22] This observation was repeated by White in respect of the lack of specification of curriculum in the 1944 Education Act.[23]

The 1902 Education Act, known as the Balfour Act, permitted the creation of local education authorities which could, if they wished, establish and maintain secondary schools. The curriculum for these schools was set out in the 1904 Regulations for Secondary Schools, which, whilst recommending that instruction should be general, with specialisation in subjects such as science and literature deferred to a later stage, made detailed recommendations as to what the curriculum content must be and the time that should be spent on each part:

> The course should provide for instruction in the English language and literature, at least one language other than English, geography, history, mathematics, science and drawing with due provision for manual exercises and in a girls'school for housewifery. Not less than 4½ hours per week must be allocated to English, geography and history; not less than 3 ½ hours to the language where one is taken or less than 6 hours where two are taken; and not less than 7 ½ hours to science and mathematics of which 3 must be for science. The instruction for science must be both theoretical and practical. When two languages other than English are taken and Latin is not one of them the Board will require to be satisfied that the omission of Latin is for the advantage of the School.[24]

The effect of these Regulations was to cast the maintained secondary schools in the grammar school mould.[25]

This curriculum, and the National Curriculum of 1988, both prescribed, and thus controlled, by government, are almost identical, save for the substitution of Technology for Manual Work and Housewifery. Music, which is included in the 1988 curriculum was originally excluded from the 1904 Regulations, but added later.[26]

The 1907 Supplementary Regulations for Secondary Schools relaxed control of curriculum in terms of hours per subject, but the academic tradition continued by, for instance, the requirement for Latin to be taught. The Regulations also provided for the establishment of scholarships to allow elementary school pupils to transfer to secondary schools after succeeding in approved tests.[27]

Circular 826, the Board of Education's Memorandum on Curriculum of Secondary Schools issued in 1913, attempted to solve the problem of providing a common course for two groups of secondary school pupils - those who would go on to further professional training or to follow a university degree course and those who would leave school at 16.The Circular was not against some limited specialisation in vocational courses, providing these did not begin before the age of 15.

The Circulars and Regulations, through their recommendations, controlled and directed curriculum. Circular 996 of the Board of Education, issued in 1917, was particularly significant in that it led to the setting up of the Secondary School Examinations Council (SSEC), with a membership drawn from universities, local education authorities and the teaching force, and to the establishment of the School Certificate examination, [28] taken at about 16 years of age and the Higher School Certificate examination, taken at about 18 years of age. Both examinations required candidates to pass in a group of subjects examined at the same time; additionally English language had to be one of the successful subjects at School Certificate level, together with a minimum of one pass at 'credit' level. Inevitably the format and orientation of these examinations had a profound effect on the content of secondary school curriculum for the next 35 years, as had the later establishment of the General Certificate of Education examinations. Clearly university representation on this Council, and the needs of university scholarship, moulded the curriculum requirement in secondary school education over this period, and, up to 1944, accentuated the difference between the low level curriculum of elementary schools and the academic curriculum of secondary schools. [29]

The Consultative Committee of the Board of Education had been set up ten days after the formation of the first Labour Government in December 1923, to consider the education of the adolescent. Its 1926 *Report* [30] recommended separation of primary and secondary education at about 11 years of age, with two types of secondary education, grammar and modern, with allocation of pupils by examination. The latter would have a curriculum similar to that for the grammar school, but more practical and shorter. The school leaving age was to be raised to 15. Although the recommendations appear to represent a step forward, essentially they reinforced a traditional view of education as providing a different curricula for different pupils according to their needs. The theme was continued in the 1938 *Spens Report* [31] which recommended that there should be three types of schooling at secondary level, grammar, modern and technical, each with its own curriculum - an academic course for grammar school pupils, a concentration on science and technical subjects in the technical school and a more practical course in the modern school. These recommendations were echoed and elaborated by those of the *Norwood Report*[32] in 1943, with a stress on differentiated curricula, to meet the needs of the three groups of pupils of differing abilities. The 1944 Education Act was generally interpreted along Norwood tripartite lines.[33] The recommendations did not meet with universal approval. In 1945, proposals for the reform of the school curriculum were published in *The Content of Education,* [34] a Report of the Council for Curriculum Reform, edited by Dr J A Lauwerys, of the Institute of Education University of London. It complained that the *Norwood Report* failed to give a lead in developing new curricula, [35] and equally criticised the 1944 Education Act for its lack of attention to matters of curriculum.[36] Lauwerys and his team recommended a planned curriculum with a common core, which would include the social sciences.[37]

It may be held to be either a glaring omission or a reflection of deliberate policy that the word 'curriculum' appears but once in the 1944 Education Act, and that in relation to a local education authority's power to compel attendance at classes held outside school premises.[38] No curriculum requirement was specified for schools with the exception of that for Religious Education (RE) which was a compulsory element in maintained schools.

There was, however, a rather more cynical view which suggested that no detail of curriculum was included as none of the drafting senior civil servants knew what to put in the Act in this regard. It was sometimes easy to disguise ignorance and irresponsibility as freedom and generosity.[39] A kinder, alternative, view was that the 1944 Education Act was concerned more with general principles than detail and the Act's drafters could assume a high level of common understanding and shared commitment amongst teachers, parents and legislators.[40] The 1944 model Articles of Government for secondary schools indicated that governors were responsible for the general direction of the conduct and the curriculum of the school but there is little evidence to show that these provisions in the Articles were taken seriously.[41] Whether by accident or design, matters of curriculum were thus left firmly in the hands of the headteachers and the teachers for the next 20 years until the early 1960s.

Control of curriculum was ultimately not just an issue of difference between central government and the teachers and their unions. Parents, too, had begun to express their views, although the facility for them to do so effectively was limited and did not really flourish until the advent of Mrs Thatcher's Conservative government of 1979.[42] The curriculum set out by the providers had not satisfied the large majority of the pupil population, nor indeed their parents. The *Newsom Report* of 1963: *Half our Future* [43] acknowledged that many secondary school children of average and below average ability were bored and apathetic and saw little point in schooling [44]

In 1968, the Schools Council document *Enquiry 1: Young School Leavers*[45] revealed sharp differences between what parents and pupils on the one hand and teachers and headteachers on the other saw as the function of education. Essentially parents wished schools to provide things which would enable their child to obtain as good a job as possible, together with the basic skills of writing correctly and speaking well and easily. Teachers saw their role with a broader application, so that they should be concerned with the development of pupils' characters and personalities, with helping them to become independent and able to stand on their own feet, and with teaching about right and wrong.[46]

The suggestions in the *Newsom Report* were important in that they initiated a debate on what curriculum should be provided for pupils of average and below average ability, the majority, and set the scene for much of the work which was carried out in the first ten years of the life of the Schools Council. Schools Council *Working Paper 2: Raising the School-leaving Age*[47] was published in 1965, and two projects, Mathematics for the Majority[48] and Humanities for the Young School Leaver[49] were early products of this focus.

The Curriculum Study Group (1962), the formation of the Schools Council (1964) and its subsequent history

The years 1944 to 1960 could be seen as a period of optimism and consensus in education, with both main political parties concentrating on educational expansion with little or no dissent, and as the golden age of teacher control over curriculum.[50] Even during this period, however, it was felt by some officials at the Ministry of Education that its traditional position of standing outside curriculum matters, and even outside public debate on these issues, was a hindrance in dealing with the challenge of curriculum revision.[51] The first shift in the traditional position was signalled by Sir David Eccles, Minister of Education, declaring, in a debate in the House of Commons on the Crowther Report [52] in March 1960, (during which he originated the phrase 'the secret garden of curriculum') that parliamentary debates should not just be about bricks and mortar and organisation, but should include discussion of what is being taught in schools. He indicated that the Ministry's voice would, in future, be heard rather more often, and positively and no doubt more controversially, on what was taught in schools and training colleges.[53]

Following a recommendation of the Crowther Report for the Ministry to conduct some basic research and collect statistics, it was announced that a new section at the Ministry had been formed called the Curriculum Study Group (CSG), composed of Her Majesty's Inspectors (HMI), administrators and an educational expert, Professor Jack Wrigley, who was Professor of Curriculum Research and Development at Reading University. The Minister indicated that CSG was to be a relatively small 'commando type' unit, making raids into curriculum, perhaps an unfortunate comparison.[54] The CSG would provide a nucleus of full time staff to organise and coordinate research studies. Its work would be linked with that of the universities, practising teachers, research organisations, professional institutions and with the remit of others concerned with the content of education and examinations.[55]

The essential point about the CSG, which was established in February 1962, was that it was not representative of the majority of educational interests - effectively only of the Ministry of Education. It was inevitable that it would run into stormy waters.

Professor Wrigley gave the CSG considerable credit for its endeavours. It had a sense of purpose, easy access to Ministers, a lack of bureaucratic control, together with a sense of excitement which was difficult to convey but easy to remember.[56] The foundations for many of the major curriculum innovations were laid by the CSG at this time, for example, of the new Certificate of Secondary Education examination (CSE). In contrast to the view of others, such as Sir William Alexander, representing the Association of Education Committees, and Sir Ronald Gould, the General Secretary of the National Union of Teachers, who saw CSG as a major threat to English liberties, Professor Wrigley felt that the CSG was a harmless, potentially valuable organisation.

The setting up of the CSG, under the joint leadership of HMI Staff Inspector R W Morris and Assistant Secretary D H Morrell and the explanatory letter about its remit to the LEAs and Educational Associations from Dame Mary Smieton, the Permanent Secretary at the Ministry of Education, produced shock waves. The existence and the terms of reference of the CSG, appeared to challenge the doctrine of decentralisation of power in public education, which had been supported by the Ministry, the LEAs and the teachers hitherto, and which was believed to be the cornerstone of freedom of thought and action in English education. The CSG was regarded as the thin end of the wedge which ultimately would lead to control of the curriculum being taken by central government.

D H Morrell, a talented and experienced civil servant at the Ministry of Education, was largely responsible for the formation of the CSG. Significantly, at the annual meeting of the National Foundation for Educational Research (NFER) in October 1962, he argued that the policy of leaving curriculum decisions to teachers needed to be reconsidered, believing that it was necessary to create a curriculum which reflected Society's needs and that teachers needed to share this task with others, whose special fund of skills and experience qualified them to express contemporary requirements. Morrell concluded that curriculum development needed the active participation of other agencies, including central and local government. [57]

The debate about the formation of the CSG and about its work rumbled on throughout 1962 and 1963. Prime Minister Harold Macmillan, in November 1962, foresaw great changes in content and techniques of teaching as curricula developed to meet the new demands of a rapidly changing world, and gave strong endorsement to the CSG.[58]

A few years earlier, in 1958, the Secondary School Examinations Council (SSEC) had set up a committee under Robert Beloe to make recommendations about a new kind of examination with a more practical orientation, suitable for students in secondary modern schools. Its Report in July 1960 recommended the establishment of a Certificate of Secondary Education (CSE) and this was accepted by the Minister, Sir David Eccles, in July 1961. He asked the SSEC to draft outlines for the new examination. The SSEC, however, was lacking in individuals who knew about the intake to secondary modern schools, since most of the previous work had been in relation to School Certificate, Higher School Certificate and GCE O and A level examinations. Although additional members had been coopted, more than half of the Committee had little knowledge of the fundamental requirements for the new examination.

By mid 1963, the Government was signalling that it had taken note of the furore created by the establishment of the CSG. In answer to a parliamentary question in August 1963 about the progress of the CSG, Christopher Chataway reported that there was an intention to form an advisory body concerned with school curriculum and examinations.

It was at this point that Derek Morrell produced what could be seen as a master stroke, which had the seeds of a solution to the basic problems thrown up by the creation of the CSG and the new challenges to the SSEC.[59] He produced a four point proposal:

> To remove the CSG from Ministry responsibility and put it under the control of a body representing all the major educational interests with neither the Ministry nor the LEAs having any controlling influence.
>
> To widen the membership of SSEC to become a more representative and relevant body for the new tasks to be addressed.
>
> To combine the CSG and the SSEC into one body responsible for the functions of both existing groups, the new body to consider matters of curriculum first and examinations second.
>
> To build into the new body a guaranteed majority of teachers, so as not to force curriculum innovation on the teaching profession, with each school still to be responsible for its own curriculum and teaching methods.

The proposal was immediately backed by the Minister of Education, Sir Edward Boyle. He called a fully representative meeting in July 1963 to consider the proposal to establish a Schools Council for the Curriculum and Examinations, under his chairmanship. A working party with Sir John Lockwood as chair was created, the terms of reference for which were defined in a resolution of that meeting and adopted unanimously by those present:

This representative meeting

(a) notes that there is wide support for the proposal to establish cooperative machinery in the fields of the school curriculum and examinations;

(b) appoints a working party comprising, under the chairmanship of Sir John Lockwood, one representative of each of the bodies present at the meeting, together with assessors and a secretariat appointed by the Minister of Education, to consider how effect could best be given to the matters discussed and to make recommendations;

(c) agrees to reconvene to consider and reach conclusions on the working party's recommendations[60]

It was also agreed that the Association of Chief Education Officers should be represented on the working party.

The working party, having met four times, presented its Report[61] to the Minister on 5 March 1964. He endorsed its conclusions, with a clear recommendation for the setting up of a body to be called 'The Schools Council for the Curriculum and Examinations'. This should be fully representative of relevant educational interests and would provide new cooperative machinery in the fields of the schools' curricula and examinations. A detailed constitution for the Schools Council, as it soon became known, was set out. The concern that curriculum decisions should still rest with teachers was reflected in the stating, no less than three times in the 14 pages of the Report, of the principle that schools should have the fullest possible measure of responsibility for their work, including curriculum and teaching methods, which should be evolved by their own staff. Patrick Ainley chose this declaration as an exemplar of the independence given to practitioners in education prior to the late 1970s in his article in the Journal of Social Policy (Vol 30, 2001) entitled 'From a National System Locally Administered to a National System Nationally Administered: The New Leviathan in Education and Training in England'.[62]

It was agreed that in each of the major committees of the new body, the number of representatives of the teacher associations would aggregate to a majority of one and on the Governing Council to two. The Council was to be free to select its own subjects for study and should have full operational control of its own staff, who were to be drawn from all sectors of the education service and on short term appointments for three or four years.

In June 1964, the Lockwood proposals, as they became known, were put to a reconvened meeting of the representative body that had been set it up. It unanimously recommended their adoption. Quintin Hogg, who was now Minister of Education, implemented them in full immediately, and the Council began work on 1 October 1964, with Sir John Maud as its first chairman.

The fledgling Schools Council was fortunate in that it took over, and could immediately address, three major themes of significant and timely interest which had been developed by the CSG. These were: an examination of the teaching of English, an investigation into the sixth form and its curriculum, and preparations for the raising of the school leaving age, planned for the early 1970s. A programme of research associated with the teaching of English was outlined in Schools Council *Working Paper 3*, [63] published in 1965. In the same year it published *Working Paper 2: Raising the school leaving age: A cooperative programme of research and development*, [64] whilst *Working Paper 4: Science in the Sixth Form*[65] and *Working Paper 5: Sixth Form curriculum and examinations*[66] were published in the following year.

The Schools Council's first *Curriculum Bulletin*, entitled *Mathematics in Primary Schools* [67] and warmly commended, was published in 1965. It was largely written by HMI Edith Biggs, who had undertaken comprehensive development work in this field in the early 1960s. In 1967, and arising from *Working Paper 2*, *Working Paper 11: Society and the Young School Leaver: A Humanities Programme in Preparation for the Raising of the School-Leaving Age*[68] was issued. The Mathematics for the Majority Project was initiated in the same year and its Continuation in the early 1970s, whilst the Science 5 -

13 Project and the Social Studies 8 - 13 Project, together with a Report entitled *Working Paper 22:The Middle Years of Schooling*[69] were other early examples of the Council's initiatives.

Given the controversial circumstances of the formation of the Schools Council, it was not surprising that wide - ranging disputes continued throughout its life. As early as 1966, for example, lengthy consideration of the functions of the Schools Council by the executive of the National Union of Teachers revealed serious discontent with its operation. In particular, teachers complained about being overwhelmed by paper, a by-product of the need to refer back and consult which was built into committee procedures. The Schools Council was never seen to achieve a great deal within a reasonable time frame.

Nevertheless, the early days of the Schools Council seemed to be characterised by a willingness to work together. Freddie Sparrow, who ultimately became Chief Research Officer at the Schools Council, spoke of working in a place alive with genuine enthusiasm and, importantly, with the strong support of the DES and LEAs.[70] This view is challenged by Plaskow, who saw the role played by the DES and the Inspectorate as always enigmatic, not helped by the limited continuity of representation of DES personnel and by reticence of HMI in expressing views in programme committees.[71] More than 12 years elapsed before central government made known its, by then, harsh view of the Schools Council in the *Yellow Book*, [72] from which time central government hostility to the Schools Council was clear. The Secretary of State took a lofty view in the document, [73] writing that the Council had done moderately well in commissioning some work in particular curriculum areas but had had little success in addressing examination problems and had scarcely begun to tackle problems of curriculum as a whole. Performance has been generally disappointing. Prime Minister Callaghan, in his Ruskin speech in 1976 was dismissive, saying, 'maybe they haven't got it right yet'.

The constitution of the Schools Council was modified on two occasions, once as early as December 1968 and substantially so in 1978. The latter modification was extremely elaborate with complex interlinking of committees and, whilst visionary in its concept, was practically speaking, difficult to operate effectively. Following the establishment of the 1978 constitution, the Schools Council continued with a heavy programme of work, including the writing and publication of a detailed appraisal of a range of curriculum issues in the *Practical Curriculum.*[74] Its issue was delayed for a short time to enable the DES booklet, *The School Curriculum,* [75] to be published first,[76] an episode which was significant, in that the latter, now first in the field, was perceived as representing the official, endorsed, version of curriculum, whilst the former was seen as a lighter weight alternative, not carrying an official seal of approval.

The Schools Council was subject to a further review of its activities by Mrs Nancy Trenaman, who, in November 1981, recommended that it should continue. Notwithstanding, Sir Keith Joseph, Secretary of State in Mrs Thatcher's Conservative government announced, in April 1982, his intention to disband the Schools Council. The Schools Council closed on 31 March 1984.

Conclusion

In retrospect, the fact that the Schools Council ever came into being in 1964 was remarkable, such were the rigid and unquestioning attitudes of national and local politicians, the teacher unions and the Association of Education Committees (AEC), in the post second world war period to 1955. They rejected even a superficial examination of curriculum and reflected the overwhelming feeling that such matters were firmly within the purview of headteachers and teachers in schools. Yet the Schools Council, which essentially concerned itself with curriculum development, was created with the broad agreement and participation of the teachers (more precisely their unions), the Association of Education Committees, and the government. It is possible that neither the teacher unions nor the Association of Education Committees and the LEAs wanted this initiative, but they took such fright at the formation of the Curriculum Study Group, that two years later, they were relieved, if not anxious, to accept the creation of the Schools Council, where their influence was ostensibly preserved.

During its lifetime the Schools Council sponsored much project activity and produced many Reports, Curriculum Bulletins and Working Papers, the fruits of the labours of individuals and of programme and subject committees, served by teacher, local authority and central government representatives. It was the only forum where all the educational bodies met, on neutral territory, to discuss matters concerning the curriculum.[77] On balance, there was ample evidence that the Schools Council supported the development and implementation of a considerable number of important studies and initiatives which were set to make a major contribution to the national thrust for curriculum change in the 1960s and 1970s. Nevertheless five educators of the 1960s remarked on the impracticable professional burden placed on teachers when they became involved in one or more Schools Council or other projects. Some further negative views about aspects of the Schools Council work and its impact were expressed by four other educators. Firstly, the Council failed to acknowledge local curriculum development initiatives and effectively caused them to expire, with teachers being colonised into Council projects. Secondly, the Schools Council lacked an overall curriculum change strategy. Thirdly, there was no culture of rigorous evaluation of materials and no means of assessing how teachers were using them. Fourthly, there was little evidence of attention being given to planned outcomes for the use of project materials nor yet to their incorporation into the mainstream school curriculum.

There was evidence, too, of the dissipation of the energies of the Schools Council - a product, in part, of the tedious internal administrative machinery associated with the workings of the complicated system of committees and subcommittees, reflecting the perceived need to consult in depth and then to refer back decisions for approval. Over time these arrangements came to be disliked by Ministers in Government and by the officers of the Department of Education and Science. It was, for example, Shirley Williams, who, in 1977, as Secretary of State for Education, displayed some impatience with the system in making clear her wish for the teacher majority on committees to be ended and for a smaller Governing Council to be established. She wanted to see the appointment of more lay members to the Council, approved by the Secretary of State and representative of the consumers of the educational end product.[78]

Since much had been made of the proviso in the original constitution of the Schools Council that continuing responsibility for the content of the curriculum and for teaching methods rested with teachers, the products of the Schools Council could be embraced or ignored by teachers as they chose, and often depended on the whim of an individual Director of Education, a headteacher, a head of department, a local authority inspector or adviser and possibly a lecturer from a local college of education. Indeed, seven educators noted that successful project implementation clearly relied upon active cooperation amongst all these agencies. As a consequence, the take up of materials was uneven at best and negligible at worst. Dissemination of news about projects was not an aspect which loomed large in the Council's early thinking and many were funded without provision being made for information to be spread amongst teachers.[79] Attempts were made to rectify this omission later, through the publication from 1968 of *Dialogue*, a termly newsletter sent to all schools, giving details of current projects.

This thread of uncertainty and lack of clear direction attended many Schools Council activities, both in terms of its administration and in terms of the implementation of projects, and contrasted strongly with the concentrated energy which characterised the work of, for example, the School Mathematics Project under the direction of Professor Bryan Thwaites and the Nuffield Primary Mathematics Project under the direction of Professor Geoffrey Matthews. The Schools Council Mathematics for the Majority Project, which was exceptionally worthy in focusing, essentially for the first time, on the needs of pupils of average and below average ability, encountered serious practical difficulties which could have been largely foreseen and managed with clear-sighted control. There was evidence of a lack of thrust and definition in the broad range of the work of the Schools Council and this was probably one of the principal reasons for its ultimate demise.

Much stress had been laid on the constitutional requirement that the Schools Council should have a majority representation of teachers on its major committees. Yet paradoxically this constitution sowed the seeds of later intensive central government involvement in this context, through the admission of HMI and DES representation on its committees and Governing Council. The advent of the Schools Council established the right of central administration to contribute to the debate and to influence curriculum development in a way that had not been acceptable during the existence of the Curriculum Study Group. Thus began the process which ultimately led, 20 years later, to the imposition, by central government, of the National Curriculum in 1988, where curriculum content was defined, and control exercised through the many directives issued to schools. It is fitting to note the view of Professor Denis Lawton in this context, echoed by Malcolm Skilbeck,[80] who asserted that the Schools Council missed an opportunity in not addressing the issue of a National Curriculum. It never seriously looked at curriculum in the round and thus never suggested a cohesive whole. The events of the late 1980s might have taken a different course had the Schools Council looked at this issue 15 or so years earlier.[81]

In the 1950s and 1960s, both the teacher unions and the Association of Education Committees were implacable in their resistance to any attempt by other bodies, including Government, to have any responsibility for matters of curriculum. Yet the broad thrust of evidence increasingly suggested that teachers were not being seen by Government, politicians or parents as acknowledging the importance of this responsibility or as devising any consistent or long term strategy for curriculum review and modification. On the whole they were naively content to continue teaching existing curricula; much testimony of the 1970s supports this view.

Despite the inception of some dynamic projects and lively initiatives in the 1960s and 1970s, and their uptake by a comparative few, it is perhaps a harsh, but justifiable conclusion to draw, that the majority of teachers failed to take their responsibilities for the curriculum seriously. For progress to take place there must invariably be change; in this context the greatest weakness, and indeed the Achilles heel, of curriculum development in school, was the freedom of teachers to ignore and reject ideas for change - almost at a whim - if they so wished. The pupils were ill-served by this haphazard approach and a large number paid the price through being subject to an outdated and often tiresome curriculum.

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Chapter three

PRIMARY AND SECONDARY SCHOOL MATHEMATICS TEXTBOOKS BETWEEN 1960 AND 1965.

Teaching mathematics in the late 1950s and early 1960s, whether at primary or secondary level, invariably involved the use of a text book and an exercise book. The author, as a primary school and a secondary school teacher and later as a teacher training college lecturer visiting schools, recalls that it was standard practice for pupils to work in mathematics lessons in this way. This was before the days of the worksheet and before the time when budgets were cut so that textbooks had to be shared. Both at secondary and primary school level, mathematics series texts were popular with teachers because they provided a ready made curriculum extending over two or more years. It is reasonable to suggest that data about text and reference books available for use in schools during this period did reflect with some degree of accuracy both the content and the methods of teaching favoured by the teachers of the day, and that the popularity of certain textbooks was mirrored by the number of reprinted editions which were commissioned.

Background

The prime focus under review, defined as broadly the first five years of the 1960s, represents a time just prior to the establishment of the Schools Council (which potentially had the strength to generate substantial change in the curriculum field, including in mathematics) and a time just prior to the establishment of the Nuffield Primary Mathematics Project and the School Mathematics Project (SMP). Other initiatives, too, were coming on stream towards 1965, for example the Midlands Mathematics Experiment (MME) and the Mathematics for the Majority Project.

The materials produced by these projects began to have some impact on the teaching and learning of mathematics in the latter half of the 1960s. But there was evidence that a groundswell of change was already emanating from institutions such as the Mathematical

Association, which commissioned Reports on the teaching of the subject in the 1950s and 1960s; these seriously questioned the content of the mathematics curriculum of the day and made recommendations for improvement in the future.

In the early 1960s there was much talk of the need to introduce 'modern mathematics' into the curriculum. A view was held that this impetus reflected concern in America about the strength of Soviet progress in the space race and that the content of 'modern mathematics' was felt to represent a much more powerful tool for use in the scientific field than traditional mathematics. This suggestion has, however, been challenged elsewhere in this study. Some commentators take a broader view. A B Evenson[1] considers that there were many reasons for the (then) current revolution in mathematics, not least the apparent inadequacies of traditional mathematics and the fact that applications of mathematics had increased considerably in the recent years; as a consequence a need arose for new and more powerful instruments which resulted in the creation and use of new kinds of mathematics. 'Modern mathematics' in the school curriculum was represented through the admission of a range of new topics into syllabuses and programmes of study, for example sets, its symbolism and language, rotational geometry, symmetry, data collection and representation.

Equally, there was, during this period, considerable evidence emerging of a new approach to the way in which mathematics was taught and presented - a change in the methodology of teaching and learning - with a stress on participatory activity by children and on 'discovery' work, especially at primary school level.

The effect of all these factors was seen in the content and presentation of books which were beginning to be published in the 1960s. Early change in content was reflected in a small number of pupils' books in mathematics, whilst some were published which might be deemed 'reference' books, principally suitable for primary stage children. These contained no traditional exercises, but offered attractive, colourful pages, illustrating, for example, different shapes - triangle, square, rectangle, circle and other mathematical features, such as circumference and diagonal - with a minimum amount of descriptive text.

At the secondary level, very few reference books of this type emerged at this time.

A survey of books available to teachers and schools between 1960 and 1965 could be seen as providing a base line from which the character and strength of changes in mathematics teaching in the years beyond 1965, both in terms of content and methodology, could be viewed.

The remainder of this chapter is divided into three sections. The first describes the methodology of the survey, the second gives a detailed analysis of the texts or series of texts which were examined and the third endeavours to draw conclusions from the survey.

Methodology of the survey

Selected on a random basis, following consultation of the University of London Institute of Education's Library card index files, a sample of 176 mathematics books, both text and reference, for use in primary and secondary schools, which were available in the 1960s, were brought from the Library store for examination. The Institute of Education Library was used as the source for this enquiry as for several decades it has held a comprehensive collection of text book material focusing on a large range of school subjects. Whilst therefore the sample was not exhaustive, it was likely to be representative of the mathematics books available to schools in the 1960s.

Of the 176 books, 15 were individual texts and the remaining 161 were defined as being members of a series, of which there were 36; a series was defined as having two or more parts or stages. In summary, there was thus an overall sample of 51 items - 36 series and 15 texts. An enquiry was conducted to ascertain how many reprinted editions of books or series of books were published, since this gave some indication of popularity. A note of the frequency of reprinting, where this is relevant, is made in the analysis which follows.

In endeavouring to categorise the 176 text and reference books which were reviewed for this study certain characteristics were identified with some confidence. Clearly, not least because of the information in the title or in the foreword, a text was intended for use in either a primary or a secondary school, although the divide was bridged in terms of content and in terms of intellectual challenge to pupils in a very few of the texts. The definition of other characteristics which could be attributed to the series of texts or other books was attempted in this manner:

Any mathematical text where the content consisted of a number of well established topics in arithmetic at the primary stage, or in arithmetic, trigonometry, algebra and geometry at the secondary stage, was defined as being 'traditional'. Examples of such content at the primary level would target activities focusing on the four rules - addition, subtraction, multiplication and division as operations and as applied to a range of measures, whilst at the secondary level - determining factors in an algebraic expression, proving a theorem in geometry, calculating the length of a side of a figure using trigonometrical tables, and computing simple and compound interest in arithmetic, would represent examples of such content.

A number of books published in the early to mid 1960s for use in both primary and secondary schools included a range of new 'modern mathematics' topics; for example, work in a variety of number bases - especially related to the binary system and its application in computing, the concept of a mathematical set and probability. The content of these books, which invariably included some traditional, well established, materials, was defined as 'enhanced'.

Where the methodology of the approach to the teaching of a topic consisted, in broad terms, of a general exploration of the subject matter, closely followed by some worked examples and a large number of practice exercises, texts of this type were defined as being 'traditional' in approach.

During this period, an increasing number of books were published, especially at the primary level, which were of a style which today could be defined as 'user friendly', even though the content was deemed to be traditional. The aim of the author was that the wording, or other presented material, should interact with the reader in a positive manner. This was facilitated in a number of ways - through the use of colour, through the illustrations, through the positioning of comments and stimulus questions as the topic was developed and in the attempt to reinforce understanding by the presentation of a summary or in the posing of some pertinent questions at the end of each section. The methodology of this type of book was defined as 'enhanced'.

In terms of categorising the approach of the books as being 'traditional' or 'enhanced', a few were found to change their stance in this regard as the material unfolded. In the following review, note is made of evidence supporting this kind of ambivalence where it occurs.

It is not possible to define any of the books in terms of just one of the four characteristics, since the content, whether traditional or enhanced, has to be presented to the reader in one form or another, be this in a traditional or in an enhanced mode. Thus, the books have first been divided into either a primary or a secondary orientation and then subdivided into four groups, as depicted in the 2 x 2 matrix which follows. A second chart differentiates between the number of individual texts and series which have been examined and a third chart quantifies the frequency of reprinting of a text or series.

A. Summary of data

secondary school texts or series

	traditional content	enhanced content
traditional approach	15 items	2 items
enhanced approach	0 items	5 items
		Total = 22 items

primary school texts or series

	traditional content	enhanced content
traditional approach	15 items	0 items
enhanced approach	12 items	2 items
		Total = 29 items
		Grand total = 51 items

Initial commentary

Of the total of 51 items reviewed (22 for use at the secondary stage and 29 for use at the primary stage), 15 at secondary level and 15 at primary level were found to have a traditional content and a traditional approach. No books destined for use in secondary schools were found in the traditional content/enhanced approach category; by contrast, a substantial 12 items for use in primary schools were identified under this heading. Enhanced content matched with traditional approach accounted for two items at secondary level and none at primary level. Five items were found in the enhanced content/enhanced approach category at the secondary level and two items at the primary stage.

B. Differentiating numbers of series and individual texts inspected

secondary school texts and series

	traditional content	enhanced content
traditional approach	7 series 8 texts	2 series 0 texts
enhanced approach	0 series 0 texts	3 series 2 texts

Total = 12 series and 10 texts

primary school texts and series

	traditional content	enhanced content
traditional approach	11 series 4 texts	0 series 0 texts
enhanced approach	11 series 1 text	2 series 0 texts

Total = 24 series and 5 texts

Grand total = 36 series and 15 texts

Initial commentary

At primary school level the data showed a heavy incidence of series of books concentrating on traditional content, with an equal number of series (11) offering this kind of content with an enhanced approach. Numbers were smaller in the secondary sector, with an almost equal number of series and texts (seven and eight respectively) presenting a traditional content and a traditional approach. Two series at this level offered an enhanced content with a traditional approach. The secondary sector led the primary sector in the enhanced content/enhanced approach quadrant with three series and two texts, whereas the primary sector offered only two series.

C. Reprinting of individual texts and series

secondary school texts and series

	traditional content	enhanced content
traditional approach	7 series, 1 reprint 8 texts, 4 reprints	2 series, 1 reprint 0 texts
enhanced approach	0 series 0 texts	3 series, 1 reprint 2 texts, 1 reprint

Total = 3 reprints of series and 5 reprints of texts

primary school texts and series

	traditional content	enhanced content
traditional approach	11 series, 3 reprints 4 texts, 1 reprint	0 series 0 texts
enhanced approach	11 series,1 reprint 1 text	2 series 0 texts

Total = 4 reprints of series and 1 reprint of text

Grand total = 7 reprints of series and 6 reprints of texts

Initial commentary

Of the 51 text or series items which were reviewed, 13, or about one quarter, were reprinted. With such a small distribution it was only possible to draw some general conclusions. Reprinting was seen in every quadrant where series or texts were represented, with the exception of the enhanced content/enhanced approach category at primary level. However, of the 13, only a few of the series or texts were reprinted extensively.

Detailed analysis of the texts

A review of individual books or series assigned to one of the four quadrants of the matrices in the investigation now follows.

Texts with traditional content and traditional approach.
secondary stage.

Perhaps the most distinguished example in this category was that of Loney and Grenville's book entitled simply *Arithmetic.*[2] First published in 1906 with reprinted editions being issued on no less than 31 occasions, six subsequent to 1945 and most recently in 1962, the material covered a whole range of topics in arithmetic - vulgar fractions, percentages, profit and loss, square roots, for example. The text was extremely dense, containing what can only be described as a solid mass of exercises and problems for students to address. The book was recommended by the Mathematical Association in the early 1900s to prepare pupils for the Oxford and Cambridge Junior Local examinations, but its very popularity, at least up till the early 1960s, suggested that it was also very useful in preparing for the GCE 'O' level examination.

Another text with an extremely long life was that written by Hall and Stevens entitled *A School Arithmetic.*[3] First published in 1908, it achieved 17 reprintings with the last four in 1950, 1951, 1954 and 1961 respectively. As with the Loney and Grenville book, the material addressed a large number of topics in arithmetic, with pupils being required to tackle a series of problems in which certain computational rules had to be applied in a wide variety of hypothetical measurement situations.

A title which reflected gender differentiation of the time was *Practical Arithmetic for Girls*[4] written by R E Harris. It ran to four reprintings between 1953 and 1962 and was directed towards the apparent needs of secondary school girls who were coming up to the school leaving age. The content suggested that there was an expectation that women would have to become familiar with arithmetical requirements associated with cooking, with earning a wage, with computing electricity and gas bills, with planning a budget and with the functions of the Post Office. The stress throughout was on the computational aspects of calculating percentages, using decimals, assessing simple interest, the whole set within the context of a range of problems.

A large number of texts or series of texts were produced to prepare students for examinations at 15 or 16+. In this category most make no pretence of doing other than addressing the traditional content in a traditional manner. *Ordinary Level Algebra*[5] by T H Ward Hill published in three parts in 1960, with part one reprinted in 1965, prepared students for the GCE 'O' level Algebra paper by considering a standard range of topics such as factors, quadratic equations, graphs and their interpretation, and gradients. The approach was one which could be thoroughly expected - an explanation of the topic, followed by exercises and problems, with a considerable number of inbuilt revision opportunities. Similarly *O Level Arithmetic*[6] by A Keith, published in 1962/3 concentrated on the whole of the requirements of the arithmetic paper at GCE 'O' level. There were numerous exercises related to a range of topics such as fractions, decimals, logarithms, square roots, the metric system and numerical trigonometry.

Some authors chose to write a comprehensive course in mathematics, in contrast to those who offered coverage of a single subject. For example, R Walker produced a series in five parts entitled *School Mathematics*[7] between 1960 and 1963 to help prepare students for the four mathematics papers at GCE 'O' level. Topics in arithmetic, algebra, geometry, statistics and trigonometry were considered consecutively in each book. The presentation consisted principally of an introduction to a topic, including some worked examples, followed by a series of exercises and problems in order to practise the relevant technique and its application. In similar vein, R H Clarke published *Mathematics for the General Course*[8] in two volumes in 1963, but for a slightly different market, in this case addressing the needs of part-time students following an engineering course in Technical Colleges.

A Revision Course in Mathematics[9] by H E Parr was published in 1962. No doubt teachers and pupils in the final year of preparation for GCE 'O' level examinations would have found the text eminently suitable for their needs. The material consisted of a large number of exercises in geometry, arithmetic, algebra and trigonometry, together with calculus up to integration techniques related to area and volume.

A short book of 72 pages entitled *CSE Mathematics*[10] by Martin and Philbrick was published in 1965, with two reprintings in 1966. The material consisted of a series of 20 tests covering a range of topics in mathematics relevant to the CSE examination; effectively the book could be seen as a companion volume to a more comprehensive mathematics course. It conveniently formed a bridge between the number of mathematics books which provided a comprehensive course on the one hand and, on the other, some texts published at this time which were essentially collections of tests. *General Certificate Tests*[11] by W A Gibby, two of which, entitled *Geometry* and *Mathematics* were published in 1960 and 1962 respectively, were designed to meet the revision needs of pupils just prior to sitting the 'O' level examination. Each book offered a number of 40 minute tests, the format of which reflected that of the examination itself - questions and problems which ranged from the short and simple to the longer and more complex.

A number of texts and series of texts in the traditional content/traditional approach category did attempt some leavening in the way in which the material was offered to the reader. *Cornerstone Mathematics*[12] by R E Harris, published in three parts between 1961 and 1963, addressed work in arithmetic, algebra and geometry. The books certainly utilised exercises and problems in the traditional mode, but attempted to be rather more 'user friendly' by the interspersion of interesting and amusing pen sketches, illustrating various features of mathematical transactions.

Modern Arithmetic[13] written by C H Hopkins and published between 1962 and 1963, consisted of an introduction and four stages; it was written for 'students who did not wish to enter University'; its stage 4 prepared students for RSA examinations. The text began by looking at the history of numbering and suggested the utilisation of the '100 square' to facilitate exercises in mechanical arithmetic. The author made an attempt to relate the material to everyday life by including some practical measuring activities and by acknowledging, for example, the way in which darts players subtract when computing scores; equally the author encouraged pupils to play with a 'magic square' to gain greater facility in manipulating arithmetical relationships. The major component of the texts, however, was the traditional diet of exercises and problems.

Shaw and Wright produced *Discovering Mathematics*[14] in four books between 1960 and 1963. Despite the title, the series consisted of a large number of routine practice exercises related to themes in arithmetic, algebra and geometry followed by a series of tests; there was a stress on enabling pupils to grasp the 'quick technique' to achieve solutions to problems. What made this series slightly different was that there was some evidence of a wish to communicate more effectively with the reader through the use of informal language and amusing illustrative diagrams.

Texts with traditional content and traditional approach

primary stage

During the period under review, the content of most primary stage mathematics books was essentially traditional; however in many cases there was discernible evidence from the mid 1950s that the approach to the presentation of material was beginning to change. Colour was used in some of the printing, explanations about the significance of topics were offered and 'pen and ink' sketches introduced. Nevertheless the underlying approach was still one where a topic was presented, some worked example of the application of a technique shown, to be followed by exercises and longer problems. Because of this ambivalence it has been difficult on occasions to allocate some texts with complete certainty to the 'traditional content/traditional approach' quadrant. An explanation is offered where appropriate.

Among the 126 primary stage books reviewed in this enquiry comparatively few fall quite unambiguously into the category traditional content/traditional approach. Of these, a series in four books entitled *Two Grade Arithmetic*[15] by Lovell and Smith, first published in 1956, was surprisingly popular in that all the books were reprinted between five and seven times. Aimed at the junior age range, the content was extremely comprehensive. A large number of examples were given and practice was achieved through a vast number of exercises, with a reserve of additional exercises in the accompanying Teacher's books. Larcombe produced *A New Arithmetic for Primary Schools*[16] between 1953 and 1962 in four books. The length of each was short, at about 44 pages, with the exception of Book 4A which contained 64 pages. The 'A' texts, (1A to 4A) were intended for the 'A' groups and were in addition to Books 1 to 4. As with other books in this category, the material consisted of a range of exercises and problems across a large number of topics in junior stage arithmetic.

A curious example where work in arithmetic and English was produced under one cover is that in the book entitled *A Junior School Revision Course, Arithmetic and English*[17] by James, published in 1961. The material, insofar as the arithmetic was concerned, targeted the application of rules, utilising practice exercises and problems. Unusually, one page was devoted to an explanation of what a 'problem' consists of. The author, however, missed the opportunity of linking together any of the material in English and arithmetic in the two sections of the book.

There was a sizable market for books which provided revision opportunities and tests in preparation for the 11+ examination. A typical example was to be found in K Anderson's books *Arithmetic Tests for 3rd year Juniors,*[18] (and a companion volume for 4th year pupils), published in 1961, which offered revision and practice through tests of mental arithmetic and through the application of mechanical skills. They also contained a number of short sharp tests, each having 12 problems. These books would be used in conjunction with a standard junior school text in arithmetic. A series of four short books (varying in length between 44 and 84 pages), which had a similar purpose, was written by V A Carter in 1961 for junior school pupils and entitled *I Work Out.*[19] The material consisted of a collection of activities involving mental arithmetic, practice exercises and problems. G D Felix published *Basic Mental Arithmetic*[20] in two books of 62 and 48 pages respectively in 1961 and 1962, the content and methodology of which was very similar to those books recently discussed; another author who offered a similar presentation was G C Crew who published *Term Tests in Arithmetic*[21] in 1962, reprinted in the same year.

It is a matter of note that in the collection of 126 books reviewed in this section, none which could be described as having both traditional content and a traditional approach was destined for use in the infant school. One could speculate that the kind of ambience which had long been understood to be the hallmark of this type of school over many years and which had encouraged pupils to become involved in practical investigations precluded the utilisation of the more formal style of text; in any case the spectre of the 11+ examination was very much in the distance.

A substantial number of books, whilst offering a traditional content, utilised colour and an interactive style of presentation in an endeavour to generate a more user-friendly approach to pupils. Some examples were:

Mathematics through Discovery[22], a series of four books for junior school pupils, was written by Dora E Whittaker and published in 1965. A Teacher's Book was also published in the same year. The cover utilised two additional colours, one within the text. The series was very popular and ran to three reprintings of the basic four books by 1967 and two of the Teacher's Book. The latter was regarded, in part, as a guide; it contained suggestions for the treatment of topics with pupils. Teachers were advised to discuss mathematical concepts with children and then to encourage them to consider the applications of appropriate mathematical techniques in real life situations. Dora Whittaker stressed the need for children to work in groups and to devise different solutions to problems, whilst being encouraged to apply their new found knowledge in entirely new situations. In the pupils' books there was an emphasis on encouraging children to carry out some experimentation before turning to written exercises and problems. A typical example concerning the measurement of angles suggested using an anglemeter and a protractor. Arithmetical division was introduced as continuous subtraction, rather than just a technique to be mastered. Book Three referred to the work of Galileo and opportunities were given for practical activities in this context in class; number bases other than ten were introduced. Nevertheless the overall content was fundamentally traditional and there were many exercises to be undertaken by pupils. What was clear, however, was that the author had made considerable efforts to present mathematics in a way in which pupils would find the subject at least tolerable and possibly exciting and rewarding, with some opportunity to develop a 'hands on' approach.

Flavell and Wakelam's *Primary Mathematics - An Introduction to the Language of Number*[23] was arguably the most popular series of mathematics books used in primary schools in the 1960s and early 1970s. Books One, Two and Three were produced in 1960 and 1961, utilising one additional colour in the text; each book was matched by a Teacher's Book and an answer book. A short supplement of 16 pages was produced in 1969 to anticipate the change to decimal currency in 1971. As with Dora Whittaker's *Teacher's Book*, Flavell and Wakelam's *Teacher's Book* devoted much of the text to a discussion of the relevance and importance of a particular mathematical topic and gave guidance on its introduction to children. Reprinting of the books began as early as 1963; there were five of Book One and three of the associated Teacher's book. A version using 'ITA' (the initial teaching alphabet) was produced in 1965.

The books were easy to handle and presented an almost square appearance, at 21 cm by 17 cm for the principal texts, - quite different from the 'portrait' style presentation of the traditional textbook. One additional colour was used on white in the printing. A range of topics of a mainly traditional kind was introduced and there was a limited amount of modern content; there were exercises, some problems, but also some inferential work for pupils to undertake. Techniques such as multiplication and division were explained at some length with practical examples, employing, for example in relation to multiplication, a picture of a milk crate. The *Teacher's Book* gave an extensive explanation of the activities which were proposed in the texts, together with comprehensive accounts of the terms and terminology used in notation and computation.

The authors went on to publish a number of supplementary books, almost as equally 'square' as the main series, at 18cm by 16 cm. Typical titles were *Way In* (1962), an elementary book on number and *Lines and Shapes* (1963); *Way In* was reproduced in

'ITA' form in 1965 whilst its original edition was reprinted twice. Reflecting the newly emerging interest in modern mathematics, Flavell and Wakelam produced *Introduction to Sets* in 1965; they later went on to produce diagnostic tests for notation and translation work in mathematics.

Holland and Chesterman authored a set of texts, Books One to Four inclusive, entitled *Oxford Graded Arithmetic Problems*[24] between 1960 and 1962. The title was a fair description of the material in the books, - a collection of both simple and more complex problems related to a wide range of topics such as computation of number and of money; shapes, areas, metrication and decimals. What made this series slightly different was that the four books were described as being suitable for children of mental ages 7-8, 8-9, 9-10, 10-11 respectively, rather than for a specified chronological age. Towards the end of each book, the reader found a page of useful words related to activities in mathematics. Significantly the author suggested that pupils 'work at their own speed' - not uncommon in later years when children began to work on topics and themes, but unusual for 1961.

Arithmetic Itself, [25] by Burn and Tamblin, was published in the *Teach Yourself* series in 1962, and utilised two additional colours. Although the content was traditional, addressing a large number of topics in arithmetic at junior school level, the approach was modified from the traditional. Whilst still offering the usual diet of worked examples, the authors made a major effort to speak directly to the reader, so that a degree of interaction was encouraged. There was much use made of the pronouns 'I' and 'you' in the text. The suggestion was made that pupils could work by themselves on the material but on balance this would seem to be difficult and explanations would still be required by the teacher.

A collection of four short books under the general heading of *Number Work* [26] with individual titles *Number Units, Weighing and Measuring, Planning and Budgeting* and *Spotlight on Forms,* by E Kraft, was published in 1962. The books were intended for use in the upper junior and lower secondary levels of education. In the text attempts were made to give simple explanations of everyday working in banks and post offices, about national insurance contributions, about the issuing of radio and other kinds of licences and on the use of cheques.

T H Flanaghan produced a set of 12 short (16 pages) booklets for use in junior schools in 1964 and 1965 entitled *Topics in Number.*[27] Each booklet, (which utilised one additional colour), addressed a particular issue, such as *Weights and Weighing, Measuring Liquids* and *Spending Money.*The content was traditional, with simple and then more complex problems, but the approach, through the use of short interesting explanatory statements, followed by the problems, represented a modification to the traditional approach.

Measuring is Fun,[28] in two books of 32 pages each by F J Vickery, was published in 1961; it stuck fairly closely to traditional content in giving pupils at the top of the primary school practice in drawing up plans and elevations - exercises in elementary technical drawing. A slight modification from the traditional approach was seen in the use of small sketches to accompany an exercise which set the given problem in a typical domestic context. The text was printed in brown in one book, green in the other.

A final example where the content and approach were fundamentally traditional yet with some attempt to modify the latter could be seen in R Harris' book entitled *Angles*[29] published for use in the top of the junior age range and in the lower age range of the secondary school in 1964. The book was described as a programmed text and advocated practical activities involving ruler and compass in measuring angles, with answers to be entered in small rectangular boxes in the book.

Texts with enhanced content and traditional approach.

secondary stage

The number of books falling into this category even at secondary school level were few, but those that did tended to be very popular at the time. Reflecting the concerns of the early 1960s, about the inadequacies of mathematics teaching and the implications, to which reference was made in the early part of this chapter, authors set out to provide fresh content, identified as 'modern mathematics'; the material was however presented in a traditional manner, often with dense text and with many practice exercises.

A group of teachers working in the English Midlands had met under the chairpersonship of Cyril Hope, who was a mathematics specialist working at Worcester Teacher Training College; they produced an experimental GCE 'O' level course in mathematics and evaluated their material through extensive testing in schools. The title was simple enough - *The Midlands Mathematics Experiment*[30] - and Books One, Two and Three were published in basic print form between 1963 and 1965 for trialing. A Report on progress and the implementation of the project was published in 1965. At a later stage a definitive Volume One was produced to serve the requirements of both the GCE 'O' level and the new CSE level examinations. Volume Two was published in two editions, the first to provide for the needs of years three and four of the GCE 'O' level mathematics course, to be followed by Volume Three to complete coverage of that course and to bridge the gap to sixth form work, and the second to meet the needs of CSE pupils. A summary of the contents of the three books gave some indication of the importance which was placed on the inclusion of new material. Book One, for example, addressed different number bases and illustrated the link between the binary system and its use in computers before discussing navigation, fractions, logarithms, decimals, sets and set language, negative numbers, areas and points of the compass. Book Two looked at estimation, transformations, probability, systems of units and further work in sets. In Book Three, students were introduced to modular arithmetic, matrices, Boolean algebra and its use in electrical circuitry, differentiation and integration in calculus, and vectors.

There was a clear attempt to modernise the content of mathematics teaching, but the presentation of the new diet was as potentially indigestible as any which had preceded it, despite some excursions into activities such as paper folding. The impression gained from reading these texts was that they were intended for brighter children who could use their intellectual abilities to come to terms with the new material whilst meeting the challenge of a traditional presentation.

One of the most popular series of the 1960s was that produced by Mansfield and Thompson entitled *Mathematics - a New Approach.*[31] It was published in five books varying between 142 and 240 pages in length between 1962 and 1966. The content was certainly enhanced - the approach traditional, however. Book One was used as the core textbook for grammar schools during the early stages of the implementation of the Schools Mathematics Project (SMP). (A full description of the Project materials, which would fall into this category, is given elsewhere in this study). Professor Brian Thwaites of Southampton University and the first Director of SMP, wrote, in a foreword to Book One, that there was a need for radical rethinking about the mathematics syllabus for schools if mathematics was to survive the ever growing and desperate shortage of competent teachers and that the subject must present a new face to young people in schools - a face looking towards the challenge of a modern technological civilisation.

A review of the topics covered in each of the five books underlined the fact that not only was new content offered but often the descriptive terminology of some traditional material was changed. For example, words such as 'coordinates', 'tabulation', 'median', 'percentile', which were to become commonplace in later years, were used comprehensively for the first time in Mansfield and Thompson's books. Topics in Book One included binary arithmetic, fractions, lattices, statistics and collation, primes, commutative and non commutative algebra, rotation, triangles, tessellations and symmetry, whilst in Book Two linear programming, pie charts, histograms, probability, the normal distribution, maps and surveying, triangulation and simple trigonometry were introduced. Book Three addressed the notion of sets with reference to intersection, union of sets and Venn diagrams, transformations, topology, analogue computing, mathematical grouping, rings, fields and matrices. Topics in Books Four and Five included mathematical mapping, further Boolean algebra, logic, flow diagrams, computer programming, isometrics, transformations and rotations, vectors, best straight line and standard deviation, all of which were relatively unknown in typical school curricula of the day.

All the books retained a fair proportion of traditional material, such as axiomatic geometry, quadratic equations, decimals and the Binomial and Remainder theorems.

Although the approach to the work was very traditional, it did appear as if the authors were trying to convey a philosophy that the new content in itself would regenerate an enthusiasm for, and interest in, mathematics.

Reference to the book entitled *Modern Mathematics*[32] by A B Evenson and published in 1962 has already been made in the introduction. The author wrote 'the purpose of the book is to give the reader an insight into the nature of 'new' or 'modern' mathematics '; this volume did exactly that with an emphasis on the descriptive. Topics such as sets, number systems, ordered pairs and logical proof were dealt with carefully and painstakingly. Whilst there was much in this book which was new, there was also much that was traditional, but both new and old content was presented in an interesting manner. The book cannot strictly be defined as a teaching text. It did however follow a broad pattern of explanation of topics in rather greater depth than most mathematics books and gave some worked examples together with a number of exercises for the reader to try. In that sense, whilst the content was enhanced, the approach tended to be quite traditional.

Texts with enhanced content and traditional approach.
primary stage

No books in the sample were found in this category at the primary stage. It is suggested that in the early 1960s when many primary schools were beginning to experiment with a more informal approach to teaching and learning it was unlikely that authors wanted to submit material, even that which focused on 'modern mathematics' content, in a traditional format.

Texts with traditional content and enhanced approach
secondary stage

No books in the sample were found in this category at the secondary stage. Traditional content had been presented in traditional format for many years and it is suggested that no author at this time was willing to modify the approach to the presentation of traditional content, especially when the goal for teachers and students alike was the passing of examinations which up till then were set in the traditional mould.

Texts with traditional content and enhanced approach

Primary stage

Measuring and Recording[33] by Taylor and Ingleby published in 1963 was representative of a new departure in the way in which information was given to children, in this case children at the infant stage. The book was large, attractive and colourful and was presented in 'landscape'. It used one additional colour on the cover and two within the text. No exercises, worked examples or problems were shown. The book was concerned with illustrating a relationship between the spoken or written word or symbol and its representation; thus 'five' and a drawing of five tomatoes. Attention was concentrated on illustrating facets of a range of numbers from 1 to 10 and from 10 to 100.The difference between cardinal and ordinal number was noted, using a staircase and a running race to illustrate the latter. Within the 24 pages the authors managed to present, in a most attractive form, illustrative sketches depicting weighing and the use of scales, measuring with tape and ruler, signposts and mileposts, maps and compass points, clocks and calendars and temperature measures. The stress was on artefacts which measure in one form or another. The book was aesthetically pleasing whilst conveying, in simple fashion, early ideas in the concepts of number and measurement.

L G W Sealey produced a number of books from 1961, under the general heading *Some Important Mathematical Ideas*[34] aimed principally at the middle to top junior age range. The covers of these books exhibited symmetrical geometric designs in different colours and shading, the general effect of which was pleasing to the eye. By way of example Book 'C1' (for this is an illustration of the manner in which the various books of the series were titled) reviewed, in 50 pages, a number of traditional topics, such as series in number, shapes, fractions, regular and irregular areas, scale and plans, heights and shadows, gear wheels and their working, bouncing balls, curve stitching, line charts, pairs of lines, square numbers, averages, percentages and ratio.

The approach to the work was innovative. Children were given a series of practical tasks in relation to each topic and expected to work in pairs to discuss ideas and possible solutions. There were no formal exercises or problems in the traditional sense; there were many questions for children to ponder and the whole could be seen as an exciting challenge. From personal experience, a difficulty which emerged in using these books centred on the measure of reading fluency of the student reader. Proficiency led to profitable use of the books, lack of it caused delay and an inadequate appreciation of what the topic was about and what was required.

Other titles in this series published in the early 1960s were *Using Mathematics, Mathematics Around Us, Learning About Ourselves, More Mathematical Ideas.* The series was very popular and Book C1, after its initial publication in 1961, was reprinted in 1962 and 1965 with a revised version published in 1967. These and similar books were in the vanguard of early attempts to introduce practical guided 'discovery' work in mathematics and were much in evidence on the teachers' in-service training courses of the day.

Another popular series at this time was *Let's Explore Mathematics*[35] in four books by L G Marsh, published for use in junior schools between 1965 and 1967. Topics in mathematics were dealt with in an apparently random fashion. The content of Book Three, for example, included estimation, weighing and measuring, plans and elevations, mathematical grouping, fractions, volumes, line graphs, the abacus, Napier's Bones, magic squares, the sieve of Eratosthenes, building bridges and solid figures using nets. Book Four addressed patterns in number, different number bases, (including reference to the binary system and its link with computing), coordinates and maps, the measurement of turning (rotational geometry), sets and relationships, including intersection and union, and the history of number.

The books were well illustrated with bold colours and black and white drawings. Children were expected to work with a partner to discuss the tasks which were set out before undertaking practical work. The series would form a very useful adjunct to a standard course of junior school mathematics.

An example of the striking difference between the formal appearance of the front cover of a 'traditional' text for use in primary schools, *Two-Grade Arithmetic*, (1956) by F Lovell and C H J Smith, and the lively appearance of the front cover of an 'enhanced' book, *Let's Explore Mathematics*, (1965) by L G Marsh now follows.

Fig 3.1 Primary stage: A 'traditional' book cover and an 'enhanced' book cover

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About 60% of original length and breadth

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About 50% of original length and breadth

Razzell and Watts produced a set of books in 1964 under the general title of *Mathematical Topics,*[36] each of 32 pages. The six books with individual titles such as *Circles and Curves, Symmetry, Probability* and *A Question of Accuracy* were aimed at the junior age range. All were attractively presented, using two additional colours on the cover and in the text. The books represented a move away from traditional treatment of subject content towards a concentration on themes and topics. By way of example, the book entitled *Symmetry* examined where it is found in nature and subsequently invited children to use an inkblot on folded paper to generate a symmetrical pattern. It then considered lines and axes of symmetry, bilateral and revolutional symmetry and suggested practical activities for children to follow.

These books exemplified a treatment of the material far different from the traditional approach. In Razzell and Watts' *Probability* pupils were introduced to the topic through a story about the predicted appearance of Halley's comet; they were then invited to toss coins to achieve some understanding of the probability of an event occurring. Subsequently, through practical activities, pupils gained an understanding of the notion of a sample and of a random sample by taking beads from a box, before considering the application of sampling in opinion polls. Issues such as 'margin of error', 'estimating large numbers' and 'long range weather forecasting' all found a place in this book.

The books which have been reviewed in this section thus far did not pretend to be text books - rather topic or theme books which would be seen as complementary to an existing scheme. However, a minority of the newly published textbooks were beginning to show some signs of a change in approach, whilst still maintaining full traditional course content with the inevitable large number of exercises for pupils to undertake. One of the most popular schemes of the day was that produced by E M Williams and E J James entitled *Oxford Junior Mathematics.*[37] The books, of which there were five, were aimed at the junior school age range and first published in 1962; a set of Teacher's books were available. The text was printed in black, the covers in one additional colour.

The evidence of change manifested itself in the way in which the authors try to catch the imagination of the readers by writing a short interesting introduction to each of the books. Book Five, for example, began with a three paragraph input entitled 'Mathematics Around Us'. It referred to the pattern of a honeycomb and a snow crystal, to the movement of the earth and other planets around the sun in an elliptical orbit. In addition, the paragraphs showed how man uses mathematics from carpentry to cooking. Subsequently, items of information and provocative questions were interspersed between exercises. These helped to illuminate the topic and assisted in carrying out the tasks which followed.

Beta Junior Arithmetic,[38] by Goddard and Grattidge and published in four books between 1962 and 1963, also offered a traditional content, addressing topics in number and measurement, money, time and shape, but the presentation was characterised by the use of additional colour in the text and two extra colours for the covers. Four Teachers' books were linked to the basic pupils' books; these contained a great deal of information for the teacher with explanations of the principles involved in the topics and guidance as to how they might be introduced and developed. Some line drawings and diagrams together with sketch maps were interspersed within the text.

J G Saunders wrote *Mathematics Alive*[39] in three books in 1964, with a linked Teacher's book published in 1965, the target audience being from second to fourth year juniors. One additional colour was used on the cover and in the text. None of these books exceeded 56 pages, and as with many of this type, developed a series of topics. In Book One, under the heading of number, reference was made to the abacus, to notation and patterns in tables. Geometrical shapes and symmetry were investigated; train and car journeys linked to time were addressed under the general heading of 'travel'. Elementary graphs were introduced, as was work involving the calendar. In Books Two and Three the same titles were utilised but the work became increasingly challenging, for example in discussing some simple mechanics involving gear wheels and pulleys. Equipment and apparatus comprising nailboards, pegboards, anglometer, chronometer, spring balance, graph paper and an abacus were needed by the children to undertake the tasks which were set for them in the books, such as 'what is the area of the school hall?' and 'what is the length of the shadow of the stick?'.

The Teacher's books gave extensive explanations of topic matter and suggested useful questions to be put to children. They also provided answers to the exercises in the text. *Mathematics Alive* broke new ground by mediating the traditional content with a considerable amount of practical and meaningful activity for children.

Two series principally for use in the infant school, but which pursued their objectives in different ways were, firstly, *Discovery Mathematics for top Infants and lower Juniors,*[40] written by 'Willbrook' in the early 1960s and secondly *Four Way Number*[41] by W M Ferrier and published in 1962. The former, using one additional colour on the cover and two in the text, was an umbrella title for a number of separate workbooks for children illustrating length, weight, time and capacity. In *Weight* children were invited to collect common but different items and to experiment with quantities of one against quantities of another using a simple balance, with the hope that out of the experiment, the concept of balancing would emerge. Non standard weight measures were used initially, eventually moving on to standard measures. A high degree of fluency in reading would be needed for the work books to be used efficiently, otherwise the process would be slowed down and be dependent on the teacher's availability to read the questions and instructions for the pupil.

The activities in *Four Way Number* were based on a series of eight simple stories, which could be read by children; additional equipment comprised a flannel graph and some toys. A Teacher's book was produced at the same time. A series of linked workbooks for pupils required them to recognise and practise using the names of common numbers and then to answer simple questions which would lead them to an understanding of addition and subtraction. The content was undoubtedly traditional, but the approach was novel and would appeal to children, even if the operation was somewhat time consuming for the teacher.

A series of three books for work at infant level was entitled *Number for Beginners*[42] and written by A Lawton in 1962. The Teacher's book of 160 pages is of considerable interest in that it made detailed suggestions for practical activities for children who were learning about the concept of number. The book would be very helpful to the young teacher in the infant school in providing for the needs of children; group activities and the use of music, singing and stories, rhymes, puppets and games were all recommended in promoting the understanding of number.

A series of five books for use in the infant school, each of 48 pages, and entitled *The Way to Number*[43] was written between 1961 and 1963 by M H Austin.The books were bright and attractive using two additional colours on the cover and three in the text on occasions. The content was traditional with a stress on number properties and relationships. Material in Book One looked at the numbers one to five, introduced work in addition and some simple problems. Books Two and Three extended the approach to more complex operations, using larger numbers and introducing the concept of subtraction, multiplication and division, illustrated for children by practical experiences and activities. There was a concentration in the approach to the work on providing the 'missing number' in incomplete statements of equality, and similarly on filling in gaps in an elementary equation. Puzzles and games were also utilised to help make number more understandable for pupils.

Books under the general heading of *Colour Factor Mathematics*[44] by H J Thompson, published between 1962 and 1964 provided an interesting conclusion to this section. In the early 1960s considerable interest was expressed in the notion of using coloured rods of different lengths and colour as teaching aids. The rods were fully integrated into a system, so that for example, a three rod plus two other three rods would equate in length to a nine rod. The manufacturers of Colour Factor material believed that since, at that time, the United Kingdom utilised a duo - decimal system in money and length they were justified in using rods of proportional length one to 12, whereas the 'Cuisenaire' material of another manufacturer utilised the decimal system, with rods of proportional length one to ten. The use of the Colour Factor materials was linked to a set of five texts to be used in the first five years of the primary school. Essentially the content of the books was traditional, but the approach, using the rods in all kinds of computation was very new and for ten to fifteen years caught the imagination of many headteachers and teachers as a means of promoting understanding of number relationships. Each pupil's book contained a detailed series of practical activities. The first year material was written in two books of 62 pages each entitled *Prenumber Mathematics* and *Number and Basic Operations*. A Teacher's book, giving the answers to the exercises, was published in 1963.

Colour Factor and Cuisenaire materials were the forerunners of other sets of material which were subsequently manufactured and relied on the principle of equating the length of rod to a specific number. The introduction of Dienes' materials enabled powers of numbers in different bases to be demonstrated in principle, utilising as descriptors the words 'unit', 'long', 'square' and 'cube'. Whilst individual units and beads had long been used in schools to help a child understand number and place value, the advent of Colour Factor, Cuisenaire and Dienes materials created the potential for a fuller understanding of these concepts.

Texts with enhanced content and enhanced approach
secondary stage

Possibly the most lively series which addressed topics in modern mathematics was that entitled *Contemporary School Mathematics (CSM)*, the St. Dunstan's College booklets, the general editor for which was Dr Geoffrey Matthews, who was, in the 1960s, the Director of The Nuffield Primary Mathematics *Project.*[45] The principal characteristic which conveys itself to the reader is the sheer enthusiasm and excitement which the authors gave to their work. The eight titles of the series are as follows: -

Matrices 1, Matrices 2, Sets and Logic 1, Sets and Logic 2, Computers 1, Computers 2, Shape Size and Place and *Introduction to Probability and Statistics.*

All were published in 1964 and varying in length between 68 and 96 pages. The covers were colourful utilising a simple geometric design made up of coloured dots. The text explained each element of the topic in straightforward language and often in amusing terms. In considering the rationale of a flow chart, for example, the point was made that socks, under normal circumstances, must be put on before shoes, not the other way round. Despite this lighthearted approach a serious attempt was made to explain the significance of the new material to the reader. There were worked examples and a number of short exercises. The pace of the introduction of the material was quite quick and the material itself was certainly demanding intellectually. The booklets offered a basic introduction to ideas and concepts in modern mathematics and would be adequate to cover these elements in preparation for the GCE 'O' level examination.

An example of the difference between the severely formal appearance of the front cover of a 'traditional' secondary school text, *A School Arithmetic*, (1908) by H S Hall and F H Stevens, and the modern appearance of the front cover of an 'enhanced' book, *Shape Size and Place*, (1964) by J A C Reynolds, now follows.

Fig 3.2 Secondary stage: A 'traditional' book cover and an 'enhanced' book cover

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About 60% of original length and breadth

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About 60% of original length and breadth

Doris Bass produced a series of substantial books between 1963 and 1966 with the title *Mathematics*,[46] varying in length from 228 and 278 pages. The first three prepared for general work in mathematics, with Books Four and Five especially directed towards work for the GCE 'O' level examination. The texts set out to develop a contemporary study of mathematics with particular attention being given to some of the newer topics; exploration by pupils as part of task activities was encouraged. Book One, for example, addressed the need for place value and the use of the zero symbol and assessed potential answers in terms of odds and evens following computation. Book Two introduced sets and Venn diagrams, ordered pairs, the Moebius Strip, bearings and the compass, whilst Book Four offered a study of different number bases, of powers and of matrices. There were however many traditional exercises for children to work on, but the discussion of ideas and concepts which both preceded and followed the exercises and problems was presented to the reader in an attractive manner. The Books constituted a fulsome presentation of course material featuring both new and traditional mathematics; they were popular during the 1960s and early 1970s.

The Scottish tradition of teaching and learning had always been respected and this was shown by the popularity of the publication in 1956 by the Scottish Mathematics Group of the first of a series of seven books under the general title *Modern Mathematics for Schools*,[47] preparing pupils for the Scottish Certificate of Education. Many teachers in the remainder of the United Kingdom also found the series useful in preparing for the equivalent GCE 'O' level examinations and Book One was reprinted within the year of its first publication. The content was a mix of traditional and modern items. On balance, as the definition of 'enhanced' in the context of the 1960s and later included both new and traditional topics such as coordinates and best straight line, which have evolved from basic graph work, these materials can find a place in the fourth quadrant.

E H Lockwood's *A Book of Curves*[48] published in 1961 was extremely popular and was reprinted twice in the 1960s. As the title suggests the book studied a number of curves - the parabola, ellipse and hyperbola. The text, which was fairly dense, was accompanied by a large number of elaborate diagrams. The book included practical activities for the reader and there were many exercises based on a study of the individual curves. This was a book which tended to discourse on the mathematical characteristics of the curves both in terms of their appearance and the related formulae; it could not be described as a text, but as a support to teacher and pupil.

The final entry in this section is that of Thyra Smith's *The Story of Measurement* [49] published in 1955. Although not a text in the conventional sense, it did address a wide range of issues associated with measurement, in a revealing and interesting manner, particularly noting the reasons why man measures and the degree of accuracy required in a specific context, for instance in measuring a spark plug gap, in working with scale models and in investigating the divergence of true north from magnetic north. The whole was presented as a story which would hold the reader's attention.

Texts with enhanced content and enhanced approach
primary stage.

Possibly the most formidable example at the primary level of books where both the content and the approach could be regarded as 'enhanced' emanated from the *Nuffield Primary Mathematics Project*[50] established in the mid 1960s. The Project materials are discussed in detail elsewhere in this study. None of its products could be regarded as texts, all were in fact Teachers' guides. The first, *I do and I understand* endeavoured to convince teachers that 'hands on' experience for children was more valuable than repetitive formal teaching. *Pictorial Representation* showed teachers how data children had collected could be organised and recorded in various cogent forms and described teaching points which can arise from this form of activity. In all the books ideas and concepts associated with 'modern mathematics'content were discussed, together with suggestions for the development of the topics; examples of children's work were reproduced from time to time.

The Nuffield Primary Mathematics project through its literature tried to encourage teachers to embrace and develop a new approach to mathematics, both in terms of new content and in terms of a new methodology of teaching and learning which advocated practical activity, group work and discussion to facilitate understanding and concept formation. The significance of the work of the Project was immense in that it represented the first major cohesive thrust towards reforming mathematics education at the primary level for many decades.

J K Forgan produced a series of nine short work books of 34 pages each in 1963 for use in junior schools and entitled *Mathematics at Work.*[51] The content contained elements of both the modern and the traditional and the approach could be described as 'enhanced'. A large number of topics were introduced with a major recommendation that pupils should involve themselves in practical activity and be prepared to use pencil, ruler, scissors and paper to carry out the tasks which were linked to the various topics; these included work on graphs, coordinates, measurement, estimating areas by covering surfaces with non standard and standard measures and representing algebraic functions, such as the parabola, through curve stitching or drawing. In the advocacy of a change of content the books were perhaps not quite as advanced as the products of the Nuffield Project, but there were sufficient examples of new work and of a new approach to give them a place in this category.

Conclusion.

The purpose of this investigation was to try and evaluate attitudes towards the teaching of mathematics during the 1960s by reviewing a sample of mathematics texts and other books available for use by teachers and pupils at the time. Definitions in terms of 'traditional' content and approach were made; similarly for an 'enhanced' content and approach. A matrix of four quadrants was established linking all four components. A subsequent chart differentiated between the number of series of books and the number of individual mathematics texts which were reviewed. A third chart assessed the number of series and the number of individual texts which were reprinted.

The principal conclusion which is drawn from these data is that schools, teachers and pupils were exposed to a powerful diet of traditional content material presented in a traditional manner, accounting for 30 items of the total of 51 in the sample. The 11 series at primary level in this category would be attractive to teachers in a junior school because they would provide a ready made curriculum extending over at least two school years and possibly over four, which, in the latter case, would conveniently cover the whole requirement in mathematics for this type of school.

At secondary level in the traditional content/traditional approach category there were roughly an equal number of series and individual texts, seven and eight respectively. Certainly, as at primary level, the series would be useful in that it addressed the total, or a high proportion of the requirement of the five year course across all the individual disciplines of mathematics such as algebra, trigonometry, geometry and arithmetic. The approximately equal mix of series and text in this category most probably reflected the particular wishes of the teachers in mathematics departments to deal with the subject matter according to their predilections, either through the utilisation of a general mathematics series or through the use of a number of discrete texts servicing particular aspects of the mathematics curriculum.

At the primary stage the substantial entry of 12 items in the traditional content/enhanced approach category would appear to reflect the advocacy of a change in the methodology of teaching generated by new thinking which was beginning to emerge. Teachers were being encouraged to present material to pupils in a more 'user friendly' style and to allow for an element of active participation by them. The books in this category, which, whilst still concentrating on traditional content with which authors, teachers and pupils were familiar, were colourful, attractive to handle and interactive in approach, and would lend considerable support to these methodological changes. There is limited evidence in the matrix that, at the secondary level, authors offering an enhanced content were prepared to adopt an enhanced approach in the presentation of their material. The conclusion must be drawn that these authors were the enthusiasts, able to convince teachers and students alike of the attraction of this new discipline.

At the primary school level, no books were found which had an enhanced content and a traditional approach. Those which offered an enhanced content were linked to an enhanced approach as exemplified in the early Nuffield Primary Mathematics Project publications. It is suggested that at this time, most authors were not sufficiently confident to write a traditional approach text or series which relied on the inclusion of a substantial amount of modern content, nor yet would such a book be attractive to teachers of the day in primary schools, most of whom would be unfamiliar with such material.

At both primary school and secondary school level the impact of the use of a series was and is considerable, the whole being seen as a curriculum in its own right rather than a collection of individual texts to service a course. Across schools there was a consistency of approach to the work which reflects the book author's order of presentation of topics. There was faith, both on the part of the teacher and of the pupils, that the series as an entity would adequately prepare the candidate for an examination, be that GCE 'O'level, the 11+ or the end of year examinations. The data in this survey suggest that at primary school level particularly, and to a lesser extent at secondary school level, the series was regarded as a vital tool in teaching and learning mathematics and hence that its status is more important than an individual text. Of the 51 items in the sample, 12 series were identified at secondary level and 24 series at primary level.

Research in the British Library to ascertain how many series of books or individual texts were reprinted indicated that this occurred in comparatively few cases - 13 instances in 51 in the total sample. However, where reprinting did occur the scope was often considerable. Flavell and Wakelam's book for primary schools *Mathematics: Introduction to the Language of Number,*[53] published from 1960 onwards, is a case in point. The series reflected a mix of principally traditional and a small amount of 'modern' content matched by a more user-friendly approach. Book One was reprinted five times from 1963 and the accompanying Teachers' book three times.

It is significant that texts which could be seen as portraying traditional characteristics both in terms of content and approach were being extensively reprinted at this time - an indicator of the needs of the contemporary mathematics curriculum. On the other hand, it is important to note that Mansfield and Thompson's *Mathematics - A New Approach,*[54] which was located in the enhanced content/traditional approach category, was reprinted substantially in the sense that Book One formed the basis of the first part of the teaching material for the successful secondary Schools Mathematics Project.

The data confirm that some books in a few categories were reprinted more than others. Inclusive of series and individual texts there were five instances of reprinting at secondary level in the traditional content/traditional approach category and four at the primary level - an aggregation of nine of an overall total of 13. The remaining four instances of reprinting are distributed almost equally amongst three other categories. These results support the suggestion that the majority of teachers at this time, favoured a traditional content presented in a traditional manner.

The overall conclusion must be that if the biases revealed by this survey reflect attitudes towards content and methodology of teaching at this time, a large number of teachers remained untouched by any of the initiatives which had been implemented from the late 1950s to modify either the content or the approach, or both. One student of the time gave evidence that her mathematics course at primary level concentrated on traditional content in arithmetic, taught in a formal manner in a competitive environment. This was echoed by a second student who remembered using colour factor rods at the infant stage - the use of which thoroughly confused her - before enduring a formal teaching and learning regime for the remainder of her primary school experience. If curriculum content was modified, often its implementation was ill-judged. Three students remembered their mathematics teaching at middle and secondary school level. For the first, mathematics was taught as separate subjects, with some group work associated with project completion. Another student reported an unhappy experience associated with first moves to modify the content of curriculum at her middle school; she was presented with what she perceived at the time as two different subjects - SMP textbook work for half the week and traditional work the other half, utilising the Beta Books,[55] an indication of the confusion to which some students were subjected in the time before the implementation of the National Curriculum.

A third student, who exclusively followed an SMP programme at her comprehensive school, regretted that the teaching virtually ignored the use of fractions, favouring rather the application of decimals - a deficiency for which she had to undertake remedial work in following her sixth form course preparing for the GCE 'A' level mathematics examination, and indeed at undergraduate level in seeking a statistics qualification.

From the appraisal of this sample of books, it is suggested that a large number of primary schools were experimenting with changes in approach to teaching the subject, whilst retaining a traditional curriculum; this is reflected in the substantial number of colourful, user friendly text and reference books which were available in schools in the mid 1960s, facilitated, according to the evidence of an educator at work at this time, by strong publisher interest. On the other hand, the evidence suggests that a number of secondary schools were beginning to offer an enhanced content in mathematics, arguing that the main thrust for change in the body of knowledge to be taught was generated at the secondary school level.

Notes

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Chapter four

THE SCHOOL MATHEMATICS PROJECT (SMP)

One of the most significant developments in school mathematics in the period between 1960 and 1975 was the establishment of the School Mathematics Project. Unlike the products of some other projects which were initiated during this period, the materials produced by the School Mathematics Project, or 'SMP' as it quickly became known, were directed at pupils of above average ability - whether in public or grammar schools in the early days of the Project or, in addition, in the top sets of comprehensive schools at a later time. Subsequently, versions of the materials were produced which were considered more suitable for pupils of average ability in comprehensive and secondary modern schools.

Background

The SMP initiative has to be seen against the background of the many social and political changes which took place in the 15 years after the end of the second world war. By 1960 many citizens enjoyed improved housing; indeed many were owner-occupiers whilst a growing number owned cars. There was full employment and a welfare state. Young people, unlike their predecessors, could look forward to becoming economically independent quite quickly. Some 25% of women, including wives, were working either part or full time and contributing to the family's disposable income. All these factors led to higher living standards and to the exercise and fulfilment of choice by individuals in choosing to purchase from an increased range of luxury goods and to indulge in leisure pursuits in a way which had not been possible before.[1] This was the time of the 'Affluent Society'.

There was evidence of considerable political movement over this period. The sweeping change of mood in the population which accompanied the overwhelming Labour victory in the 1945 election resulted in the creation of an atmosphere of urgency in the early postwar phase, which manifested itself in active planning for expansion in universities, in technological education, in schooling and in local education authorities.[2] There was an expectation that politicians would initiate programmes which would facilitate major improvements in the lives of men, women and children. The school leaving age was raised to 15 on 1 April 1947 by Ellen Wilkinson, the Minister of Education, although neither she nor the Labour Party generally appeared keen to depart from the tripartite system which essentially supported a different curriculum for grammar, technical and secondary modern schools.[3] However, over the next 15 years, a groundswell developed which would ultimately lead to the general introduction of comprehensive education at secondary level, fuelled, on the one hand, by increased aspirations and, on the other, by mounting frustration on the part of parents, particularly in London and the big conurbations in middle and northern England. George Tomlinson, Ellen Wilkinson's successor, approved the London School Plan in 1950, which aimed to make London schools comprehensive, although its first manifestation, Kidbrooke School, did not open until 1954 and even then was not fully comprehensive in composition. C P Snow's lecture[4] in 1959, *The Two Cultures and the Scientific Revolution,* finished with a strongly critical attack on the rigid and crystallised pattern of English education whilst the Crowther Report of the same year[5] took a similar view. A H Halsey and Jean Floud,[6] in supporting comprehensive education, saw it as a means of enhancing social mobility and of moving towards an egalitarian society.

Harold Wilson reinforced the pressure for change in his 1963 Scarborough Labour Party Conference speech with his rousing vision of 'The Britain that is going to be forged in the white heat of this (scientific) revolution',[7] whilst in the same year, and specifically about secondary education, the Conservative Minister of Education Sir Edward Boyle (according to Brian Simon a sympathetic and knowledgeable supporter of reform from above), had moved so far as to say at the annual conference of the Association of Education Committees in 1963 that 'the time has come to abandon the idea of the 'bi-partite' system as the norm'.[8] Both major political parties had become aware of the importance of being seen to promote change in education, albeit that the manner of implementation for each was to be different.

The tripartite system of secondary schooling persisted until late 1960s and had resulted in a differentiated curriculum for grammar and secondary modern schools, essentially, in the context of this study, mathematics for the former and arithmetic for the latter. This approach reflected the continuing preoccupation with pupils' 'ability' and its consequence in terms of the programmes offered to diverse groups of students. However, suggestions for improvement and change were beginning to emerge. The author took part in early activities in the mid and late 1950s designed to develop a broader programme of mathematics for secondary stage pupils which was more relevant to their everyday lives. A few text and reference books with a colourful and lively presentation which linked mathematics and the environment were just beginning to be published.

This study describes in detail several of the initiatives which emerged as a consequence of this pressure for change - for example the Mathematics for the Majority, and the Nuffield Primary Mathematics projects - the general thrust of which was to bring mathematics (in contrast to arithmetic) to a much wider student audience, focusing in the former case on pupils capable of average or below average attainment and in both cases on a pedagogy which advocated physical manipulation of appropriate materials together with the utilisation of the environment to promote concept formation, an understanding of mathematical relationships, and the role of mathematics in everyday life. Strong support for these approaches came from the conclusions of Jean Piaget and from those who described and interpreted his work, from HMI Edith Biggs, to whom reference is made elsewhere in this study, and from the generation of college of education lecturers responsible for professional methodology courses throughout the 1960s.

Nevertheless, in spite of these social, political and educational changes and the moves to broaden the appeal of mathematics for all students, it was in the curriculum for *selective* schools and hence for the higher attaining pupils in both North America and Europe that lively and major reforms were first seen at this time, perhaps most noticeably through the introduction of elements of 'modern mathematics'.[9] In England, one of the key projects of the 1960s - The School Mathematics Project (SMP) - was an example of this development. The leaders of SMP were drawn from independent and public schools and had close links with universities. The Project's director was Bryan (later Sir Bryan) Thwaites; its development and meteoric expansion was largely his responsibility.

The rest of this chapter is divided into three sections. The first explores the origins and history of the SMP Project, the people involved in it, the educational base from which their ideas emanated and the special nature of their ideas. The second concentrates on the new syllabuses which it developed for GCE 'O' and CSE level examinations in mathematics together with the distinctive nature of the SMP textbooks, both those which students used to prepare for the GCE 'O' level examination (Books One to Five inclusive, 'T' and 'T4') and those which were produced at a later stage for pupils preparing for CSE examinations (Books A to H inclusive). It then goes on to examine the content of both sets of books and endeavours to assess the significant differences between the two in terms of a number of characteristics. The third section of this chapter focuses on results and assesses the overall impact of the School Mathematics Project and its materials, both in the short and longer term.

Origins and history of SMP

The history of how SMP came to be started is of considerable interest, not least because this development represented a grass roots initiative by a number of public school teachers and some university lecturers who focused on the needs of able children in selective schools. In 1957, a conference was convened at Oxford on the personal initiative of John Hammersley, fellow of Trinity College, Oxford and Reader in mathematical statistics. Hammersley, educated at Sedburgh School and at Emmanuel College Cambridge, was a statistician with industrial and research connections. He had been a graduate assistant in the design and analysis of scientific experiment team at Oxford from 1948 to 1955, a Fulbright Fellow in 1955, before becoming senior research officer in the Institute of Economics and Statistics in Oxford and later still senior research fellow at Trinity. He was a champion of the teaching of mathematics in the context of its wide range of contemporary applications.[10] The Oxford conference, with 103 members, brought together representatives of industry, commerce, Government sponsored organisations and research mathematicians on the one hand and lecturers in higher and further education and teachers in selective secondary schools on the other. Hammersley proposed a number of changes in curriculum content as a basis for discussion - in summary, concentrating on applied mathematics and some 'modern' pure mathematics. He envisaged less arithmetic, less manipulation of formulae, less Euclidian geometry, but more statistics, probability, abstract algebra, vector analysis and topology.[11] No consensus about new content emerged, but the conference signalled the beginning of a sustained attack on secondary school mathematics.[12]

In 1959, Louis Rosenhead, Professor of Applied Mathematics at Liverpool University, chaired a second, larger conference at Liverpool of 218 members drawn from occupational locations lower down the academic hierachy,[13] on the theme of 'mathematics in action', with Dr Frank Land as vice-chairman - a dynamic mathematician, author, and formerly vice principal of Borough Road College in the 1950s before taking a post as Senior Lecturer in Education at Liverpool University[14] in 1959. Rosenhead set the agenda in his chairperson's address and made it clear to delegates of the conference that the content of mathematics syllabuses was a topic for discussion.[15] By this time, two groups were emerging - on the one hand an alliance of university mathematicians and employers of graduate labour - the latter prepared to invest resources in conveying their 'requirements' in respect of the curriculum to teachers in the selective sector - and on the other, an articulate group of ATAM members, drawn from a broader catchment area, including colleges of education - who wished to see some post-1800 algebraic content included in the curriculum.[16]

These two groupings had consolidated their positions by 1961, when Bryan Thwaites, Professor of Mathematics at Southampton University, convened a third conference in Southampton. He built on the work of Hammersley and Rosenhead and included them as members of an advisory committee which he set up to consider reform. Some 130 delegates from schools, universities and industry attended. The conference concentrated on the need for curriculum change in mathematics and was organised to produce a 'body of opinion' which led directly to the establishment of the School Mathematics Project[17] and the production of an 'ideal' mathematics syllabus. The conference report was written by Thwaites,[18] with a foreword by Sir David Eccles, Minister of Education, in which he stressed that curricula must be brought up to date and quality improved.[19]

Thwaites was instrumental in ensuring that all three conferences enjoyed significant media coverage, particularly through *The Times* newspaper which sponsored full publication of the proceedings of the first two conferences.[20] His access to members of the House of Commons and the House of Lords in carrying forward his argument that a crisis existed within mathematics, both with regard to the curriculum and the impending shortage of teachers of the subject, showed evidence of his formidable public relations skills and powerful connections.

These conferences broke new ground in bringing together representatives of a wide range of disciplines. The involvement of industry and commerce - both key users of mathematics - had important implications in shaping new directions in English school mathematics, for they provided financial support for the School Mathematics Project and also influenced, to a certain extent, the thrust of new curriculum.

Thwaites, born in 1923, attended Dulwich College and then Winchester College. He took his first degree at Clare College, Cambridge and was placed in the first class of the mathematical tripos in 1944; he subsequently obtained a Ph.D. at London University. His career history was interestingly varied. He took the post of science officer at the National Physical Laboratory in Teddington from 1944 to 1947. He then went on to be a lecturer at Imperial College from 1947 to 1951 before becoming assistant maths master at Winchester College from 1951 to 1959. Following his stay at Southampton University, he became Principal of Westfield College in 1966. He was appointed Gresham Professor of Geometry at the City University from 1969 to 1972. His interests ranged from aerodynamics to medical administration, becoming chair of the Northwick Park Hospital Management Committee and a Council member of the Middlesex Hospital Board. He was co-founder and co-chair of 'Education 2000'.

Thwaites' role as an applied mathematician with a national reputation and wide ranging contacts ensured that he was able to exert a major influence on the course of change. He was in touch with colleagues in both universities and public schools who felt as he did; he had strong empathy with the views of his close contacts in industry who told him that the school mathematics curriculum of the time was not compatible with their practical needs. His dynamic influence on the reform of mathematics education was pointed up by Cooper[21] who argued the need for intellectual leadership in any project. Thwaites, in his key role as entrepreneur within the mathematics community, clearly demonstrated his ability in this regard. Here was a man with a mission to modernise the mathematics curriculum, albeit, in the first instance, in selective secondary schools.

In September 1961, following the third conference, a group of four men meeting in Winchester - Dr Martyn Cundy, Senior Mathematics Master at Sherborne School, who was an assistant editor of the Mathematical Association's *Gazette,* (and who later became the Deputy Director of the SMP), Mr T A Jones, Senior Mathematics Master at Winchester College, Mr D A Quadling, Senior Mathematics Master, Marlborough College and Professor Thwaites, joined very soon afterwards by Mr T D Morris, Senior Mathematics Master at Charterhouse School - agreed to work together on developing materials for a common, radically new, syllabus, and to set up a procedure whereby the Examining Boards would provide new matching GCE examinations. This meeting was effectively the genesis of the School Mathematics Project. Geoffrey Howson joined the group in early 1962. All had the experience of being pupils at independent or grammar schools. The writers were influenced in their work by their concern about the ever-widening gap between mathematics at school and the treatment of the subject at university, together with the lack of reference in school mathematics to the growing range of newer applications of mathematics, including computing. The aim of the SMP courses was to offer a distinct blend in 'modern mathematics' of the pure - the concept of function, mapping, transformation, vectors and matrices - and the applied - statistics, probability, linear programming, networks and computing.[22]

Despite Thwaites' initiatives, support for reform was generally lukewarm. Michael Price noted that 'oral evidence points to a less than sympathetic view of the SMP amongst some of the Mathematical Association old guard',[23] whilst the Association distanced itself from comments by Thwaites about the inevitable effects on curriculum reform of the then current shortage of mathematics teachers which had developed since the end of the second world war. This topic was the subject of his inaugural lecture at Southampton and underlined the vital dependence of good mathematics on the supply of good teachers.[24]

The annual *Reports*, set out in the *School Mathematics Project - the First Ten Years*,[25] represented a commentary on the development of the work of the Project over 10 years from 1961, first as a research project and then as a charitable trust. In the first (1961/62) BryanThwaites described the major challenges which were faced in writing and implementing a new syllabus. One problem for the GCE Examination Boards was of devising an appropriate examination. Before producing new papers, they needed to know that a sufficient number of schools would enter pupils. The matter was resolved by the agreement of eight schools to work to a new syllabus. The senior mathematicians of the four schools - Charterhouse, Marlborough, Sherborne and Winchester - were joined by others - A J Penfold, from Battersea Grammar School (later to become a distinguished lecturer at the Institute of Education), D J Holding from Exeter School, D E Mansfield from Holloway School and Miss J E Harris from Winchester County High School for Girls. This group set themselves the task of providing both a new syllabus of work for the whole grammar school range of 11+ to 18 years which would adequately reflect the modern trends and usages of mathematics and a complete set of associated textbooks and Teachers' guides, which were to be published by Cambridge University Press. Bryan Thwaites identified two guiding principles for the Project's work,[26] the first of which was as follows:

> Of over-riding importance for us, however, is that the syllabuses and the associated teaching methods should be developed as a practical outcome of classroom experience, rather than a result of theoretical discussions round committee tables. The value of the contribution which we feel we might make to mathematics teaching lies as much in the methods being used to change the syllabus as in its final content, and, if any claim needs to be made for the SMP's work, it will rest primarily on the experimental teaching and the experience of it gained in a group of schools.

Thwaites' principle was strongly supported by Howson who, in 1987, argued that projects must be seen to be school based and must rest on the foundation of teachers' willingness to cooperate to solve their problems - a role in which the School Mathematics Project clearly succeeded. The provision of materials and advice alone was seen as insufficient[27]

Thwaites second guiding principle focused on using mathematics in the modern world:

> It will be recalled that the aim of the Project is to develop a school syllabus and the teaching and GCE examinations associated with it, which will reflect the true nature of mathematics and its up-to-date uses more adequately and vitally than, in our view, do the traditional syllabuses.

Howson sounded a cautionary note in pointing out that the fulfilment of this aim could not be guaranteed, for much depended on the dominant influence of the teacher and his or her response to the new approach rather than specifically on the textbook or the syllabus.[28]

The origins of the SMP lay in a series of conferences which addressed the functionality of mathematics teaching of the time and created an opportunity for curriculum reform. There were a substantial number of participants, of whom Thwaites became the leader. The teachers who were involved were principally based in independent, public and grammar schools and had strong links with universities. Their ideas, which were expressed in the SMP materials, were grounded in classroom experience and focused strongly on contemporary applications of mathematics. Industry acknowledged the status of this grouping and provided financial resources for the Project and, to a degree, influenced the content of the materials.

Project materials

Production

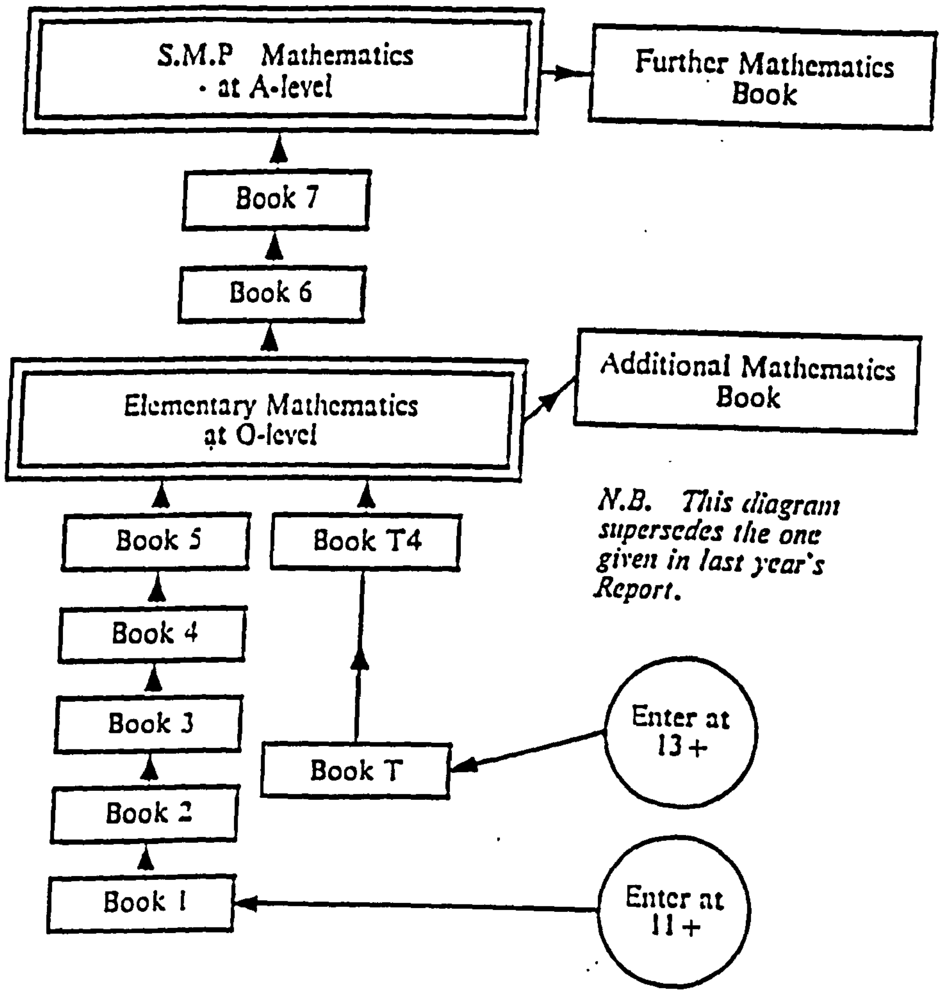
All the eight schools started to work to a new scheme for teaching in September 1962.

At 11+ the four grammar schools agreed to use the text *Mathematics: A new approach - Book 1*[29] by Mansfield and Thompson. This was the first of three texts which had been tried out at Holloway School for some years. At 13+, an entirely new book, written in the 12 months to September 1962, was to be used in duplicated form in all eight schools. This book ('T' for 'transition') was to be the first of two which would cover the final two years of preparation for the 'O' level examination; the second book was known as 'T4'. The Project paid particular attention to the needs of pupils who had already embarked on a traditional mathematics syllabus and who, in accordance with the wish of their schools, would be taking the new GCE 'O' level examination. Book 'T' was particularly appropriate for public schools with an entry at 13+, or for pupils in other schools where the first two years of their course had been 'traditional' in orientation. At the time of the writing of the first annual *Report,* covering the period July 1961 to September 1962, it was anticipated that three Examining Boards, Cambridge, London and Oxford & Cambridge, would collaborate to set a common examination to be taken for the first time in July 1964.[30]

It took several years to produce the complete set of SMP/GCE texts, the last towards the end of the decade. It was a point of principle for this Project that writing was always followed by rigorous trialing of the materials in schools and their subsequent revision where necessary. This was seen to be a major strength of SMP; its products were not only grounded, but also refined, in the classroom.

The schematic diagram which follows illustrated how Books One to Five, together with T and T4, served the needs of pupils who had different previous mathematics experience and who aimed to sit for the GCE 'O' level examination. The diagram also detailed other material which became part of the SMP scheme - for example, *SMP mathematics at 'A' Level* and, to satisfy the need to provide further stimulus for pupils at GCE 'O' and 'A' levels, *Additional Mathematics* and *Further Mathematics.*

Fig 4.1 The Series of SMP Texts for 'O' and 'A' Level Work [31]



The first serious reference to a new focus of development for the SMP Project - the production of materials for pupils who would be taking the CSE examinations - was made in the 1966/67 *Report.*[32] It had transpired that much of the work already developed in Books One to Five, which was prepared essentially for pupils aiming to take the GCE 'O' level examination, was being used in schools for pupils in non-GCE streams. Thwaites seemed to be placed in something of a dilemma. In a private discussion with Cooper he said 'Our initial objective was to rewrite just the 'O' and 'A' level (materials) but (Books) 1 - 5 were being used for sub - 'O' level pupils. This was a bad thing - perhaps positively harmful - since they were not written for such less able pupils'.[33] Howson too, according to Cooper, agreed - 'People were already using Books 1 - 5 lower down. They needed stopping, the books were not right for this ability range'.[34] It could therefore be inferred that, despite the fact that SMP's raison d'etre had thus far been to produce materials designed for selective school pupils, the SMP management were now being pushed into producing new materials suitable for non-GCE pupils, either through popular demand or financial incentive or a combination of both. Whatever the reasons, a new team of writers drawn from comprehensive, grammar and independent schools who wished to enter their average ability or low attaining pupils for the new CSE examination[35] was assembled to produce an entirely new set of texts, to be labelled A to H inclusive. The material was modified from the original set of Books One to Five. These texts 'would be suitable at least for the top 75% of the intelligence range'.[36] Presentation was to be simplified and the complexity of the language and arguments used in the original series was to be modified. The match between the sequence of topics in the two series was to be maintained in principle. Book A was published in June 1968 and Book B in October 1968 with further books of the series planned for publication at six monthly intervals.

Although the principle of substantial testing of materials in schools was adopted for the first set of publications leading to the GCE 'O' level examination, it appeared that in 1966 - 67 neither the Project Director nor his colleagues were willing to embark on a similar process for the production of the SMP/CSE materials - nor were they willing to produce a specimen CSE examination syllabus.[37] However, 12 months later, there was evidence of something of a change of heart, for it was noted in the 1967/68 *Report* that the Project had made much progress in formulating a suggested syllabus for a CSE examination associated with Books A to H and in collecting specimen questions for that examination.

Similarities and differences between the two series

The Project Director, in the 1967/68 *Report,*[38] made clear the major distinctions between the work of the two series - principally in terms of the character of the language which was used. Thwaites took the view that whilst complex language may be important for developing mathematical arguments, simpler language of a non-mathematical kind may be necessary to introduce a topic to a beginner. Elsewhere Thwaites emphasised the importance of concentrating on the practical aspects of mathematics and on drawing the mathematics out of real life situations. This was reflected in the tasks which were set for pupils at the beginning of each of the chapters in the books in the two series and in this context, there was some acknowledgement of the work of Piaget. Thwaites stressed the investigatory approach which was encouraged in the texts and which permitted concepts to develop for pupils through practical involvement and experimentation.

The authors of Book A, the first in the 'main course' series preparing pupils for the CSE examinations set out in the Preface the differences between the two series under a number of headings which are summarised below:

The emphasis on preliminary investigation and questioning of pupils which was developed in the GCE 'O' level books had been enhanced in the A to H series. A practical activity labelled 'prelude' was to be found at the beginning of each chapter and another activity labelled 'interlude' was introduced occasionally in the texts; this might focus on mathematical research in the classroom or on a follow up activity such as a visit to a farm or a factory.

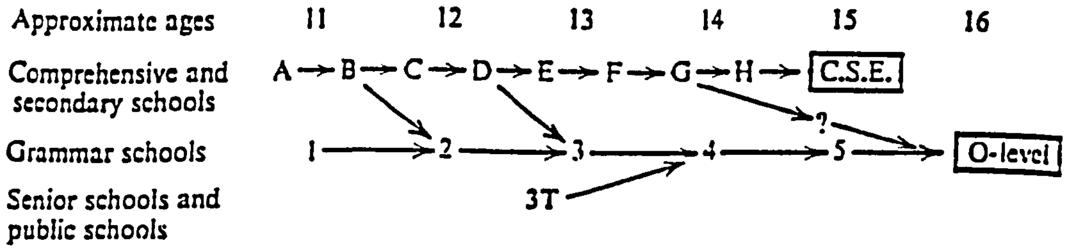
The 'O' level books had assumed rather more knowledge of some subjects in mathematics than had been found justified for the average pupil; therefore, in books A to H, more time was to be given to the treatment of the earlier stages of a topic preceded by some additional sections on preliminary work.

The chapters in books A to H were subdivided into several parts for two reasons; firstly to allow pupils to absorb the material in one part before moving on to its development in the next and secondly, by providing a smaller interval between one discussion of a topic and the next, to reduce the need for extensive revision.

Although the intention was to provide a match between the sequence of content coverage in both series there were to be some changes in the A to H set. For example there was no early chapter specifically on sets; ideas surrounding this concept were introduced where necessary and a full treatment (including an explanation of the Venn diagram) was postponed until later in the series.

Language did not prove to be the only difficulty which the new SMP authors faced. The notion of making a match between the subject materials in Books One to Five and Books A to H respectively did not prove workable; for example the CSE group realised that the content of Books E to H could not be kept as close to Books Three and Four as originally planned.[39] A new pattern of matching was recommended and is illustrated in the following diagram which is reproduced from *The School Mathematics Project: The First Ten Years*. This page is additionally interesting for the insight it gives into some of the contemporary thinking of the authors and in particular how they viewed the clear cut division between the requirements of high attaining children and pupils of lower streams in secondary schools.

Fig 4.2 The Relationship between SMP Texts 1 - 5 and SMP Texts A - H[40]



(ii) *The able child in the comprehensive school.* It is felt that in many schools which will quite reasonably use only Books A–D in the first two secondary years, there will be a significant number of children who need to be stretched by further material. Thus supplementary books of enrichment mathematics are needed for ages 11–13.

(iii) *From Books A–H to O-level.* It was originally thought that Book 5 might be used as a transition from Book H to O-level. This turns out not to be a feasible idea and yet the need for this link remains. It is suggested that it might take the form of three new books from Book G.

(iv) *The lowest streams.* Books A–H are not intended for the lower streams in secondary schools (the bottom quartile of the intelligence range), but it is felt that help *is* needed at this level and that the S.M.P. should try to provide it. Random assistance in the form, for example, of supplementary material for one or two years of the A–H course would probably not be satisfactory. It would be better to prepare a complete course of material, maybe consisting of work cards and covering, say, the age range from 9–16.

(v) *Teachers' Books.* It is also suggested that further books for teachers should be produced. They might be written on the lines of the review chapters of Book 5, so as to give teachers an overall picture of topics that might interest their children. Such books might also be valuable for students at Colleges of Education. In addition, there might be books covering methods of teaching and learning mathematics, so as to lay as much stress on methods of presentation of school mathematics as on content.

The SMP material was made virtually complete by the production of a Teachers' guide as a companion to each book in both series. Although the text was dense and occasionally difficult to comprehend, each guide attempted to chart the development of a topic for the teacher through a number of short statements. There were some suggestions in the text about the responses which might be expected from pupils and some analysis of their possible errors in attempting an exercise.

Appearance

The appearance of **Books One to Five**, preparing pupils for the new GCE 'O' level examination, could be described as formidable. With dimensions approximately 11 inches by 8 inches, heavy and with hard back covers, decorated in a simple yet powerful style, they were easily identified amongst a mass of other books then available to schools. Even today, 35 years later, the style is unmistakable.

In modern parlance the writing style endeavoured to be interactive. Pupils were able to be practically involved in simple research. They were invited to investigate the significance of mathematical symbols - for example - an examination of all the numerals up to 99 to determine the place value of each digit used in each number. Some exercises in clock face arithmetic introduced, in a less formal way, work in different number bases and ultimately led to a consideration of binary numbers, preparing for the introduction of the principles of operation of the computer. Although SMP has perhaps earned a reputation for introducing pupils to 'new' or 'modern' mathematics, it needs to be noted that there is much in these books which is traditional in orientation. The text was lively and posed questions which were designed to raise awareness of, and generate interest in, mathematics and mathematical ideas. It was clear that the authors were enthusiastic about their task. Yet having said that, the text was consistently dense and included many routine exercises in a traditional format. Diagrams and charts were in black and white. The books had an academic feel to them and the pupil was left in no doubt that he or she was addressing a serious discipline.

The appearance of **Books A to H** was in complete contrast to that of Books One to Five, with soft back covers and traditional dimensions of approximately 8 inches by 5 inches. The text in Books A to H was easier to read, much less dense and used more space in the presentation of the materials. The books had black and white illustrations and many sketch diagrams. The depth of coverage and the complexity of the exercise questions was much less intense in Books A to H than in Books One to Five. Practical involvement in tasks associated with individual topics such as number patterns, number bases and symmetry was encouraged; there were questions of the type "we have had this result in one experiment, what do you think will happen if....?". Topics in modern mathematics were introduced throughout the series, such as sets, subsets, tessellations, number bases other than ten, leading to the use of binary numbers and their application in computer technology, together with simple activities and exercises to illustrate bearings, distances and coordinates.

Books A to H, whilst considerably less fulsome in content and presentation than Books One to Five, and with some interesting titles for some chapters, were still basically academic in approach with exercises of the traditional type still in evidence. The orientation and style of the content of Books A to H appeared to be similar to that developed elsewhere for the same target audience, such as that of the Mathematics for the Majority Project (MMP), reviewed elsewhere in this study, but it would be fair to say that the SMP Books A to H were different, in that they promoted a 'product' approach, where the emphasis was on the presentation of a redefined content, rather than on a 'process' approach, such as that adopted by the MMP, where there was a greater emphasis on the facilitation of learning opportunities for pupils.

Modern mathematics content

There follows an overview of the new 'modern mathematics' content of both Books One to Five inclusive and Books A to H inclusive, since the addition of these items into the syllabuses could be considered as one of the most important features of the changes in mathematics teaching of the 1960s and 1970s

(a) SMP Books One to Five, Books T and T4.[41]

It is apparent, in appraising the chapter arrangements, that each book addressed not only new material but offered a sequential across-the-board treatment of topics in different mathematical disciplines - arithmetic, geometry, algebra, trigonometry and statistics. An appreciation of the balance between 'old' and 'new' or 'modern' mathematics can be made by referring to the GCE 'O'level syllabus on which the examination of July 1964 was set, and this is reproduced as Appendix G to the study.[42]

In Book One there was an early reference to sets as a mathematical concept, to membership of sets, to subsets, to intersection and union of sets, to the empty set, to the Venn diagram and to the notation which was used to represent these ideas; this was closely followed by topics focusing on coordinates, ordered pairs and map references. It was necessary for students to become familiar with the newly popularised symbols for greater than, >, and less than, <, and also with the manner in which relationships were described, using the new symbols; for example, $\{ (x,y): y > x + 2\}$

New ideas concerning the measurement of rotation, polar coordinates, bearing and distance linked to radar scanning were introduced. Construction of polyhedra in 3D shapes and the importance of a 'net' in this task were stressed. In arithmetic a new look was provided through the introduction of addition and subtraction tasks in bases two, three, eight and 12, noting the special link of base two to computer processing.

Although in 1962 decimal currency had not been introduced in the UK, the chapter on decimals and fractions encouraged students to express not only money but weight and other non-denary measures of the time in decimal form, whilst activities in area and volume were seen as essentially practical, for example as an opportunity to cover surfaces with tiles (area) or to fill a space with sand or with cubes (volume), rather than just using and memorising formulae, such as length x breadth = area, for a rectangle. The graphical treatment of linear relations was promoted so that students would have opportunity to practise, for example, the technique of extrapolation from given data.

A great deal of attention was paid to developing the topic of symmetry, both from the point of view of identifying its characteristics and of the construction of figures and models with a desired symmetry. Rotational symmetry was examined, as was that associated with reflection and congruence; paper folding leading to the identification of symmetrical properties associated with right angles, angle bisectors and isosceles and equilateral triangles was encouraged. An algebraic description of symmetrical properties using coordinates was introduced - for example -

$(x,y) \rightarrow (-x,y)$ or $\rightarrow (y, x)$; $y = x + 2 \rightarrow y = -x + 2$.

Statistics had long been a tool for professional mathematicians but the SMP syllabus introduced this important topic in a simpler form for younger pupils, with a stress on the collection and organisation of data and their representation in histogram, line graph and pictogram form. The significances of the arithmetic mean and the median were examined. A critical evaluation of data from books and experiments was encouraged.

Book Two began with activities related to topology, a new topic concerning the geometrical properties and spatial relations unaffected by change of shape or size of a figure and using networks, roads and maps by way of practical examples. Routine work in number was complemented by a study of number patterns, for example in the manner in which the repeated addition of a number created the sequence of a multiplication table and where the addition of the resulting digits formed a repeating pattern itself, of the Fibonacci series, where each number is the sum of the two preceding numbers, for instance (0),1, 1, 2, 3, 5, 8..., of square numbers, which are illustrated by the build up of a sequence of square patterns, for example (1), 4, 9, 16, 25..... and of a magic square, the criteria for the establishment of which consists of a square array of numbers, where no number may appear more than once, and the sums of the various rows, columns and diagonals must be the same.

One major feature of Book Two, which also contains much which could be regarded as traditional material, was the emphasis placed on the activities associated with reflection, rotation and translation, and, in particular, the special attention which was given to the symbolic representation of these activities; for example - the representation of the direction and magnitude of a translation as $(x,y) \to (x+a, y+b)$.

Some introductory work was developed in probability and random sampling with practical experiments using coins and dice and with attention being given to a mathematical expression for 'the chance that' and 'the odds against'; a new approach to proportion was developed through similarity and constructions, stressing the ratios of corresponding lengths, areas and volumes.

Book Three developed the topics of reflection, rotation and translation further still, whilst clock face arithmetic illustrated work in number bases other than 10.The study of graphs represented traditional fare in a mathematics syllabus but the topic was enlarged in this book to stress rates of change - for example - average velocity over an interval and instantaneous velocity at a point.

Computers and programming were two topics developed in this book, with recommended activities utilising different number bases - but with a concentration on the binary in view of its link with the computer - together with an introduction to flow diagrams and programming.

Statistical work was further extended with a concentration on frequency distributions and means of grouped distributions, extrapolations, interpolations and interpretations from and of graphs; some attention was given to misleading graphs which was important at a time when graphical representation was becoming increasingly popular in the media. Range and mean deviation were introduced as was the topic of the scatter diagram leading to basic ideas on correlation, 'goodness of fit' and 'best straight line'.

Book T represented an attempt to service the needs of pupils who had followed a traditional GCE 'O' level mathematics course up to the age of 13 and who now wished to enter the new SMP GCE 'O' level examination at the age of 16. In effect it aimed to bridge the gap between the old and the new. Book T contained 16 chapters of which half addressed 'new' topics and half traditional. Sets and their intersection, union and complement, universal and empty sets, together with their representation in a Venn diagram, featured in an early chapter as did simple transformations through reflection and rotation together with line and rotational symmetry. Work in statistics was to be found in a chapter headed 'Displaying Data', the coverage being in an abbreviated form compared to that seen in Books One and Three. Enlargement, (scale), was given prominent coverage and stressed the comparison under this heading of the invariant nature of some features associated with enlargement and the changed nature of others. Graphs were seen as descriptors of relationships utilising linear and non linear functions. The exponential and square laws were introduced. The penultimate section of Book T introduced some work on coordinates and then continued with a chapter on binary arithmetic.

Book T was republished in more polished form in the summer of 1965 as a result of experience in the classroom. Book T4, the final 'leap' to 'O' level and the sequence to Book T was also published in 1965. Together they formed a pair which set out sufficient material to cover two or three years' work and were especially suitable for pupils who had begun their approach to GCE 'O' level work in public schools at 13+.

Books Four and Five, the continuation of the sequence of Books One to Three, completed the basic set. 'Modern' mathematics material in Book Four concentrated on networks, computers and programing, probability and statistics. This book was eventually seen as the concluding volume in the series which prepared pupils for the GCE 'O' level examination. The original Book Five ultimately formed two texts - *Additional mathematics Part 1* and *Additional Mathematics Part 2* which became the basis for more complex sixth form work and as such beyond the scope of this study.

(b) SMP Books A to H inclusive [43]

Books A to H constituted the 'Main School Course' and were written principally for pupils in classes preparing for the Certificate of Secondary Education (CSE). New examinations in mathematics were sponsored by a number of CSE examination boards from 1966.[44] The scope of the examination was largely controlled by teachers. Under the mode three arrangement for the examination, the substance of part one of the examination was common to a number of schools. Part two examined syllabus material which had been devised by the teachers in each individual school, with the results subject to external moderation.[45]

The chapter titles for the Main School Course were set out on pages 208 to 210 of *The School Mathematics Project: The First Ten Years.* They are reproduced as Appendix H to this study.

The approach to reviewing these materials will be the same as for Books One to Five, that is only items which could be defined as 'new' in the sense of coming under the heading of 'modern mathematics' are listed; as is noted above the content and the depth of the material in this series is considerably less fulsome than in the first series. Overall, there was still much which could be defined as traditional.

The modern mathematics material in Book A focused on a consideration of the following topics: number patterns, coordinates, number bases, symmetry, polyhedra. In total, 27 pages of text were devoted to investigations into number, targeting for example, prime numbers and triangular, square and rectangular number patterns. 21 pages were devoted to work in the number bases of four, five, six and ten (but not yet in the base of two). Ideas in symmetry were illustrated through activities such as folding an ink blot and bisecting a shape, whilst attention was also given to rotational and line symmetry. The concept of describing a position or a line with coordinates was introduced, as was that of degree measurement of angles through the notion of rotation, using in the first instance the clock face. A chapter was devoted to polygons and the measurement of their angles and angle sums whilst a further chapter dealt with simple polyhedra and the utilisation of 'nets' in creating these three dimensional shapes.

Book B introduced tessellations and promoted investigations into which regular identical shapes will or will not fit together without gaps. This idea was further extended by linking with activities in symmetry to determine which symmetrical shapes might tessellate and which might not. For the first time the concepts of sets and subsets were introduced using the non numerical mode first - for example - Set A = { the months of the year} and then moving on to the numerical - Set B = { even numbers less than ten}. However, very little of the set notation and symbolism was used at this stage; its introduction was rather more of a measured process.

Assessment of areas by covering surfaces with identical shapes and comparing the results was encouraged; the concepts of the 'ordered pair' and the 'directed number' were introduced together with mappings between sets. Under the heading of statistics, different ways of illustrating data, such as the bar chart and the pie chart, were shown, with examples of situations where such presentations might be used - as in a vehicle survey. The work on angle measurement in degrees in Book A was followed, in Book B, by an extension into fixing a position through a compass bearing. The binary number base and its relationship to computing was dealt with in some detail as was its practical application through punching holes in a computer tape, which was, at that time, the principal method of translating information into the binary code. The duodecimal number base and its practical application was reviewed - for example, in connection with shillings and pence and feet and inches.

The 'modern mathematics' topics in the later books in this series (C to H inclusive) are summarised in the following paragraph. Inevitably many of the topics recurred, but the treatment was in greater depth. The content showed a parallel with some of the content in Books One to Five, but the distinction was in the level of complexity of both the treatment of the topics and the language used.

The principal modern mathematics topics in Book C comprised relationships and their representation in graphs, reflection and rotation, networks, statistics and symmetry, whilst those in Book D were enlargement (proportion), vectors, arrow diagrams and mappings. Book E addressed sets, matrices, probability, networks and polyhedra whilst Book F looked at matrices, statistics, isometrics, computers, programing and probability. Book

G's content included correlation and lines of best fit, linear programming, statistics and networks. Book H looked again at linear programing and statistics and then introduced the topics of translations, shearing and stretching

Results and Impact

In 1964 919 candidates took the first SMP/GCE 'O' level mathematics examination, 3,526 in 1966, 6,642 in 1967 and 10,980 in 1968.[46] The last three figures represented 1.56%, 2.99% and 4.85% respectively of the total entries for the GCE 'O' level mathematics examination in the summer of 1966, 1967 and 1968 for boys and girls combined.[47] SMP/GCE 'O' level entries had thus risen more than ten fold in the four years 1964 to 1968, and more than one and a half times in one year, between 1967 and 1968. The SMP/GCE 'O' level examination entries continued to rise at a substantial rate throughout the first half of the 1970s. In 1970 there were 20,100 entries for this examination, 38,739 in 1973, 44,898 in 1974, 53,659 in 1975 and 57,493 in 1976, after which the increase began to slow. The proportion of SMP/GCE entries of the grand total of the GCE 'O' level mathematics entries in 1973 was 16.5%.[48] Flemming, in giving a detailed account of the history and progress of the School Mathematics Project in *Curriculum Research and Development in Action*,[49] pointed up its able management and considerable success, in, for example, providing an examination which catered for 20% of the totality of GCE mathematics 'O' level candidates (62,691) by 1977. The materials were well received by many teachers who were disenchanted with existing syllabuses. An educator of the period, referring to the dissemination of both SMP and Nuffield Primary Mathematics Project materials, took the view that teachers generally, whether at primary or secondary level, were bored with teaching 1940s 'mathematics' and were pleased to be exposed to new content and suggestions for new methods of teaching.

Taken together the SMP/GCE 'O' level and CSE materials became enormously popular in schools, either used as a basis for a teaching scheme, or as a source of topical ideas for teachers to draw upon. Howson, Keitel and Kilpatrick[50] commented that, overall, they were ultimately in use in over 50% of English secondary schools whilst the Scottish equivalent, SMG, completely dominated secondary schools north of the border. Cooper,[51] in a survey of two southern English counties in 1976, some 15 years after SMP's inception, noted that 28 of 37 comprehensive schools were primarily using SMP books, the majority in preparation for the CSE examination.

During the period when the SMP Books A to H were published, the number of comprehensive schools was growing. Mathematics teachers were reluctant to commit pupils at an early stage of their secondary schooling to enter either for the CSE or the GCE 'O'level examination. As a consequence, three further books, X, Y, and Z, designed to lead on from SMP Book G, were written by the Project, to prepare pupils to take the GCE 'O' level examination. The route to 'O' level via SMP Books A to G and Books X, Y, and Z became more common than that via SMP Books One to Five, whose use was increasingly confined to selective schools.[52]

The SMP materials were popular for a number of reasons. Firstly, they were adopted by far more schools than those from any other project because SMP had a larger and more experienced pool of authors on which to draw, as well as the financial backing that enabled it to deal efficiently with the administrative problems that arose.[53] Secondly, the text books in both series were written by dedicated, practising, enthusiastic teachers and were subject (at least in the first series) to rigorous classroom trials; this was reflected in their style and content. Thirdly, the books could be introduced by teachers and used immediately by pupils as a 'ready made' complete mathematics scheme. Fourthly, each text book was supported by a Teachers' guide which amplified the treatment of topics in the pupils' books. In contrast, the Mathematics for the Majority Project and, with some limited exception, the Nuffield Primary Mathematics Project, produced only a set of Teachers' guides which, whilst they included suggestions for activities, essentially required teachers to devise their own work programmes for pupils - an activity which represented a major charge on a teacher's time and energy.

Another reason for the success of SMP was to be found in the response of younger mathematics teachers, often a new breed of graduates with the recently established B.Ed degree working in secondary modern and later in comprehensive schools in the late 1960s and 1970s, who, anxious to promote their careers as examination orientated subject specialists, became a new professional subculture seeing SMP as an aid to achieving their goal. There was a belief that to be involved in SMP mathematics placed them and their schools in the vanguard of real development in mathematics education. Andrew Brown, for example, a staff member of the Institute of Education, recounted that he had been successfully taught SMP mathematics at secondary school by a lively teacher using Books One to Five; he had then gone on to teach SMP mathematics in a comprehensive school using Books A to H.[54] His enthusiasm was matched by that of an educator of the time, who also taught mathematics in the 1970s and favoured the use of SMP materials, although using the books as a source for appropriate lesson content rather than pursuing the course as an entity, largely because of some language difficulties for pupils.

Cooper,[55] argued that the advent of this new group produced a groundswell which led to a redefinition of the former arithmetic based curriculum as a mathematics (including modern mathematics) based curriculum for some pupils, especially those planning to sit for the CSE examinations. He concluded that it was the SMP materials which provided the stimulus for change and ultimately affected the programmes for pupils outside the selective system.[56] John Ling contended that, with some reservations,[57] the SMP A to H books generated a far richer content than had been seen hitherto in textbooks used for CSE courses, which generally were uninspiring and derived by simplification and omission from traditional GCE 'O' level courses, although he acknowledged that the SMP material was more suitable for pupils of 'higher ability' and 'greater maturity'.[58] Elsewhere, however, Ling noted that by the mid 1970s, the SMP A to H Books were being criticised as unsuitable for both higher and lower attaining groups and for the middle group on the grounds of readability and content.[59] He believed that the writers of the A to H series of books seriously underestimated the difficulties pupils had, particularly in number work, and with decimals and fractions.[60] Personal experience of working with middle and lower attaining groups indicated that pupils' understanding of these topics depended on a flexible approach to teaching and the undertaking of many, varied, practice exercises - of which there were a limited number in the materials of Books A to H.

The SMP reaction to the growing dissatisfaction with the materials of Books A to H was to hold a major conference in Bristol in July 1976, to discuss what it should do next for pupils of 11 to 16 years. Subsequently, the SMP embarked on a new course for this age range, the aim of which was to produce mathematical material for a wide range of pupils, with the exception of the bottom 15%, in terms of attainment.[61]

The attraction of SMP work for some younger teachers had a further effect of partially deskilling older non-graduate teachers, largely because they were unable to cope with the new material and approaches. The modern mathematics content represented an indirect threat to their seniority and produced reactionary views. In Cooper's survey of reactions to SMP[62] one teacher described the materials as 'too wordy, too much reading - not enough exercises; unrelated to real life',[63] 'OK for the top 30%' but that 'any modern mathematics topic is for entertainment only'.[64] An educator offered another point of view - SMP was unpopular because the new content of Books One to Five and the methodology of its presentation to pupils were seen by some teachers to be just as formal as traditional mathematics content and methodology.

Hammersley, an applied statistician, who organised the Oxford conference of 1957 prior to the establishment of the Project, attacked SMP in 1968 for 'enfeebling mathematical skills by modern mathematics and similar soft intellectual trash in schools and universities',[65] whilst Professor Morris Kline, in his book *Why Johnny Can't Add: The Failure of the New Math*[66] gave a jaundiced view of the imposition of 'modern maths' on teachers and students.

Mrs Margaret Hyman of Putney High School, delivering her Presidential address to the Mathematical Association in 1975, acknowledged that the SMP writers had produced some interesting texts 'for the top 10% of the ability range'. However, in her view, the SMP materials, and other new curricula, had done nothing towards tackling the basic problem of providing a course which the majority of children were capable of enjoying or would find satisfying either in their future work or for its own sake. She called for a differentiated curriculum - 'we must stop trying to teach abstract mathematics to all pupils and concentrate on mathematics for some pupils and competence in arithmetic as a first priority for the majority'.[67] Margaret Hayman's condemnation of SMP and similar material - for use by pupils capable of average or below average attainment- is too sweeping. While accepting that SMP underestimated the challenge faced by some pupils in the application of basic arithmetical techniques, the materials did go some way towards exposing students in the second and third quartiles of ability to a more modern, interesting and exciting content.

An overview of all the materials, both for GCE 'O' level and CSE preparation, gives an impression of a traditional academic approach, relying heavily on exercises, but with a leavening of practical activities, interesting questions and the occasional diagram. Unlike other projects of the time, SMP was more concerned with product rather than process.

While the content of Books One to Five, and Books T and T4 was seen to be highly appropriate for pupils preparing for the targeted GCE 'O' level examination, the authors of Books A to H may not have achieved their aim of producing effective teaching materials specifically aimed at the CSE clientele. It is the author's view that SMP lost its unique identity when it produced Books A to H - they are too similar in appearance and style to others available at this time. Undoubtedly they were extremely popular with some teachers, and this is reflected in their sales. The content was challenging in a way which some other publications for the same market were not. Nevertheless, it is clear that the materials of the SMP Books A to H essentially failed to satisfy the overall needs of the range of students for which they were written. An educator of the period took an austere view, believing that SMP Books A to H were lacklustre and unsuited to the middle sets in comprehensive schools.[68]

Howson maintained that the result of publishing SMP Books A to H (described by him as a subset of Books 1 to 5), was less than happy, principally because the Project was unable to exert influence on the locally based independent CSE examination boards in the manner it was able to do in respect of the GCE examination boards.[69]

From another standpoint, Dowling[70] reported the views of Howson and Griffiths who, in 1974, seemed to suggest the possibility of a relationship between 'ability', as measured by the distinction between the numbered and lettered series on the one hand and social class on the other:

> With all types of pupil the final teaching language may have to take account of their social language. It is no good using the language of mandarins to children of factory workers.... For example the early SMP books T and T4 were written in the language of mathematics specialists. These (books) were rewritten for grammar school boys and the resulting Books 1 to 5 were again rewritten in the language of CSE children as Books A to H.[71]

As Dowling points out 'The relationship between CSE pupils and the children of factory workers is almost irresistible'.[72]

That SMP was fiercely independent and unwilling to be subject to controlling influences which liaisons with other groupings might produce, was illustrated in the rejection of a £30,000 grant from the Schools Council to assist in pursuing research as part of an international project for computing for schools. Thwaites, writing in the 1969-72 *Report,*[73] in explaining the decision to withdraw from the Schools Council project, despite the completion of some initial work, underlined the fact that ultimate control and ownership would rest with the Schools Council; put very bluntly, it was obvious that Thwaites could not tolerate this. An oblique look at how SMP, and Thwaites in particular, were viewed can be seen in Schools Council papers[74] written in 1974 when the National Foundation for Educational Research (NFER) proposed an evaluation of SMP materials. Internal papers and the exchanges of letters between the Schools Council, (involving Professor Jack Wrigley) and the NFER, referred, inter alia, to criticisms which were generated about the Project materials and to a lack of certain skills demonstrated by students who followed SMP courses. The relevant Schools Council Programme Committee turned down the request for the evaluation to proceed, perhaps because of the estimated cost of the proposal at £85,000, but a curiously guarded handwritten note almost at the end of the papers - ' Bryan Thwaites has knowledge of the SMP (evaluation) proposal but not in the Round 1 form' - indicated that Thwaites would not have been told of the exact format of the proposed investigation - perhaps because his response might have been explosive.

In assessing the strength of SMP it is worth noting that a number of key actors who contributed to the process of redefinition of the mathematics curriculum, including Sir Bryan Thwaites, straddled occupational boundaries in their professional lives. Many associated with the SMP were subsequently occupationally mobile. The conjunction of the influence of the educationalist, the industrialist and the politician forged a confident and effective force in conveying the benefits of SMP to teachers preparing pupils for CSE, GCE 'O' level and 'A' level examinations and for 'additional mathematics' work. Nonetheless, in the author's view, the Project's principal focus was clear in targeting the needs of the academically able and, although the SMP team was prepared to help other pupils by producing a set of books for pupils capable of 'average' attainment in comprehensive and other schools and by listing some suggestions for activities with less able children, there was a reluctance to stray too far from what appears to have been their chosen, academic, brief. The School Mathematics Project offered little challenge to the dominant assumptions of the time which supported differentiated provision for different ability groups.[75]

The *Reports* which spanned the years, 1961 to 1971, recorded in *The School Mathematics Project - The First Ten Years'*[76] were written in dynamic fashion and reflected almost a crusading zeal to improve mathematics curriculum and its delivery. It is clear that SMP fired the imagination of teachers both nationally and internationally and the Project administrators were hard put to it to meet the demands on their services. Thwaites and his colleagues also worked energetically to promote the SMP overseas. Versions of SMP Books One to Four, under the auspices of the 'East African School Mathematics Project' (EASMP), for use by high attaining students in Kenya, Uganda and Tanzania, were produced between early 1966 and 1968. Book One was rewritten by a lecturer at the Institute of Education at Makerere University College and designated EASMP Book One, while, following similar practice, EASMP Book Two, modified from SMP Book Two, was produced by a group of schoolmasters based in Mombasa.[77] A draft version of EASMP Book Three was written by a group based at the Curriculum and Research Centre in Nairobi and sent to schools for trialing in January 1968.[78] After a period of indecision centring on the placement of management responsibility for the Project in East Africa, EASMP Book Four was produced later in 1968.[79] However, an educator who worked in Government service in the area at this time pointed out that the impact was relatively short lived, not least because of the decision of the leaders of some states, for example President Banda of Malawi in 1970, to reinstate a traditional mathematics curriculum.[80] Another version of the SMP Books One to Five materials for use in the Far East, including Hong Kong and Malaysia, was projected in 1965, to be written by Mr B Miles of St. Paul's College in Hong Kong; [81] it was anticipated that this version would be suitable for use in English medium schools, in, for example, Hong Kong and Malaysia.

A contract between the School Mathematics Project and the American Science Research Associates Incorporated (SRA) was drawn up in 1965 to produce the 'O' level series of SMP texts in a form appropriate for American pupils.[82] It was planned to publish an American edition of Book One by September 1967. However, the contract was broken by SRA and publication did not take place.[83] Additionally, project materials were translated into Arabic, Chinese, Dutch, French, German, Italian, Polish, Spanish and Turkish and were adapted for use in Australasia, the Caribbean, and West and South Africa.[84] Nevertheless, Howson argued that adaptations of SMP materials were often unsatisfactory in that the principles of operation on which the materials were based were lost in the physical translation.[85] The team visited many other countries to promote the concept of SMP and to discuss the implementation of the materials, including the Canary Islands, India, Mauritius, Nigeria, Singapore, Sri Lanka, Switzerland and Zambia.[86] While there was considerable initial interest in SMP and its programmes, heightened by the support of western aid agencies, evidence suggests that a number of factors, including the suspicion on the part of senior government ministers and ministry officers in some countries of the developing world that SMP materials were inappropriate for students' needs, prevented their long term assimilation in many overseas countries.

There were considerable changes in the late 1950s and early 1960s in the social, political and educational contexts in England and Wales, but paradoxically it was the major independent schools - traditional in outlook, but with extensive links with universities - which generated major reform in mathematics teaching, and which were responsible for the redefinition of its curriculum in England and Wales. A particular example of this endeavour was seen in the establishment of the School Mathematics Project under the dynamic leadership of Bryan Thwaites, who, as a consequence of his liaison with industry, facilitated the provision of substantial financial support for the development of the Project's materials and, through his media and political contacts, ensured widespread publicity for the enterprise.

With some qualification, SMP was largely successful in its aims; its materials permeated secondary schools of all types throughout England and Wales. Its management was efficient at every level - in the writing of the materials, in their trialing and in their distribution, and in the provision of in-service training for teachers. Indeed, SMP could be said to have a continuing influence in the year 2001, nearly 40 years after its inception; some of the materials of the differentiated '11 to 16' series, first tested in schools from about 1980, can still be found in curricular source libraries.[87] These include SMP Book R2,[88] published in 1986, covering a range of topics, such as gradient, area and sampling. SMP Book B5,[89] published in 1987, addressed speed, maps and plans, and squares and square roots while SMP Book YX1,[90] published in 1995, embraced items such as tangents and curves, rational and irrational numbers, and graphs to solve equations. However, the emphasis on certain 'modern mathematics' topics such as the notation and idea of a set, and Venn diagrams, found in the first SMP publications, has declined almost to the point of extinction in the content of the SMP books still available and in modern secondary school mathematics texts, for example *National Curriculum Mathematics*[91] by K M Vickers, M J Tipler and H L Van Hiele.

In an intense period of curriculum renewal in the 1960s, SMP offered teachers an attractive mix of subject matter - sets, transformations and other 'modern mathematics' topics - reflecting ideas developed under the auspices of UNESCO - whilst at the same time encouraging the study of exciting mathematics themes such as probability, statistical representation and number bases; some traditional content was retained. The pedagogical ambience suited many teachers - neither too didactic nor too child-centred - with a greater emphasis on content but with some concession to a changed methodology of teaching. On balance, evidence suggests that in the first 15 years of the Project's life, SMP got it just about right in its provision for the top 20% of students capable of high attainment, but was less sure footed and only partially successful in its targeted provision for pupils capable of average attainment.

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Chapter five

THE MATHEMATICS FOR THE MAJORITY PROJECT

The Mathematics for the Majority Project is of considerable interest for four reasons. Firstly, it was initiated by the Schools Council, unlike others such as the Schools M-athematics Project, which remained independent of the Schools Council despite attempts on the part of the Council to establish a cooperative link, and the Nuffield Primary Mathematics Project, which was funded by the Nuffield Foundation. Secondly the specific focus of the Project centred on the needs of 'pupils of average or below average ability', invariably in secondary modern and comprehensive schools; to single out a large group of pupils of this character for special attention was extremely unusual. Thirdly, its focus anticipated the raising of the school leaving age in England and Wales to 16 in 1972, elaborating on the conclusions of the Newsom Report of 1963, *Half our Future,*[1] and the Schools Council Working Paper 2 *Raising the School Leaving Age,*[2] published in the same year. Finally, the Project was succeeded by a continuation project of similar name, which became operational in the 1970s.

The setting up of the Mathematics for the Majority Project represented a good example of how the Schools Council preferred to work. The first stage was to produce a Report or Working Paper. After due deliberation a project or an initiative was started - in this instance leading to the production of Teachers' guides.

Background

As with other projects initiated in the 1960s and early 1970s, the thrust of the Mathematics for the Majority Project has to be seen against the background of social changes of the time. The school leaving age was raised to 15 in 1947 and 20 years later there was strong tide of opinion to raise it further to the age of 16. In the late 1960s and the early 1970s, the abolition of the 11+ examination in local authorities across the country was gaining momentum. The implementation of comprehensive education was seen as a means both of meeting the needs of pupils of all intellectual abilities under one roof and also of encouraging social equality.

The fundamental question, however, which exercised education professionals - including particularly those who were in favour of change - centred on *what* should be taught to the majority of pupils who were now to remain at school in their sixteenth and seventeenth year, and who manifestly needed a new curriculum challenge. The formal grammar school diet would suit only a minority and would disappoint the many. Schools Council *Working Paper 14, Mathematics for the Majority,*[3] aimed to suggest sensible and worthwhile answers to this question.

The rest of this chapter is divided into three sections. The first explores the origins and antecedents of the Project, the people involved in it, the educational base from which their ideas emanated and the special nature of their ideas. The second concentrates on the Teachers' guides which were published by the Project, reviewing their content and particular orientation. The third section of this chapter attempts to assess the overall impact of the Mathematics for the Majority Project and how far it succeeded in its aim of bringing more exciting and understandable mathematics to pupils.

Origins and antecedents of the Project

In 1965, in *Working Paper 2,*[4] the Schools Council described its programme of preparation for the planned raising of the school leaving age to 16 years in 1970/71. Note was made of studies it had commissioned in several subject areas, including in mathematics, to establish whether development work could be initiated to help teachers design appropriate five year courses for pupils who would now be staying at school until they were 16. By 1967, the Schools Council had published working papers on the humanities, *Society and the Young School Leaver,*[5] and on science, *Science for the Young School Leaver.*[6]

Working paper 14, Mathematics for the Majority: A programme in Mathematics for the

Young School Leaver,[7] published in 1967, was written by Philip Floyd, Principal Lecturer at Rolle College of Education, Exmouth. He later became Director of the Mathematics for the Majority Project. In the 1960s, college of education staff were in the forefront of advocating changes in methodological practice and in curriculum content in schools. The former tended to receive more attention in primary schools, the latter more attention in secondary schools. As a mathematician, Philip Floyd was part of this impetus. The lively suggestions in this Schools Council *Working Paper 14*, reflected a creativity and an approach which would have been seen as unique at the time, outlining, as it did, a vigorous programme in mathematics for the young school leaver. Floyd quite clearly demonstrated his understanding of the implication of raising the school leaving age - to take place within five years - that of devising a modified curriculum in mathematics reflecting contemporary developments in the scientific, mathematical and environmental fields.

The terms of reference for *Working Paper 14* required him to address the needs of pupils between the ages of 13 and 16 years of 'average and below average ability'- those who fell within the range of attaining a Grade 4 CSE pass as the upper limit and a lower limit which stopped short of the requirement for children to be offered remedial treatment in special schools or special classes in the mainstream - that is roughly half of the pupils in secondary modern schools and the equivalent ability range in comprehensive schools.

The first part of Philip Floyd's paper was in the form of a Report on the existing situation in regard to mathematics teaching. It began by summarising a number of contemporary experimental projects in mathematics such as the Schools Mathematics Project, directed by Bryan Thwaites, the Midlands Mathematics Experiment, led by Cyril Hope, the work of the Scottish Mathematics Group, the Shropshire Mathematics Experiment led by Raymond Heritage and the 'Contemporary School Mathematics'[8] initiative led by Geoffrey Matthews, then Director of the Nuffield Primary Mathematics Project. Floyd made the point that the majority of these projects, whilst supported by able and devoted disciples, were principally concerned with work for abler pupils and hence did not impinge on the work for the ability range which was being considered in this Schools Council document.

The paper then addressed the state of mathematics teaching in England and Wales in the mid 1960s which, particularly in relation to secondary modern schools, made for gloomy reading. It provided a significant commentary on the pressing problems associated with the teaching of the subject. A survey conducted by the National Union of Teachers entitled *The State of our Schools,*[9] based on returns from 394 schools, showed that only 22% employed a graduate specialist to teach mathematics, 53% needed to use other subject specialists to teach mathematics and 25% had no specialist teacher at all; it was estimated that 43 in every 100 schools required additional specialists to cover their programmes. Further, in Wales, the 243 teachers in secondary modern schools in 1961/62 with responsibilities in this field offered a range of qualifications in mathematics which varied from an Honours Graduate (7), through GCE A level (55), to a lower, or even to no qualification at all, (115); it was noted that, in summary, 'about 80% of secondary modern schools in Wales have no specialist qualified teachers of mathematics'.

Floyd, in describing the range of facilities and equipment available to teachers and the pupils of average and below average ability, commended the creative provision on the part of some teachers, but argued that the general picture reflected poor and inconsistent support for pupils and teachers alike. Another feature which exacerbated the situation concerned the practice of deploying the relatively few specialist teachers of mathematics to service the needs of the examination streams, thus leaving the teaching of pupils in the non-examination groups in the hands of the non specialists. The reasoning behind this arrangement was quite understandable; the new secondary modern schools were anxious to show that they too could achieve some success both in the traditional and new examinations, such as those created for the Schools Mathematics Project and also in relation to the CSE. Floyd made an assessment of the credit/debit impact of introducing an examination programme into secondary modern schools; he found that such provision gave a bold incentive for some pupils, whilst on the other, creating a system which could lead to an '11+ syndrome', with joy for the 'haves' and sadness for the 'have nots', who would not be entered for examinations.

Floyd noted that there was evidence that there had been a great deal of concern in the years prior to 1965 about the mathematics content of courses for students in the fourth year - and potentially for the future fifth years - in anticipation of the raising of the school leaving age to 16. The *Newsom Report* [10] and the *Schools Council Working Paper 2,* [11] had stimulated debate and Floyd acknowledged the existence of some well-planned integrated approaches to a new curriculum. However, the emphasis thus far in planning courses in mathematics for the targeted ability group appeared to centre on a restricted diet of problems about national, civic and personal finance, and on the gathering of statistical data, together with their visual presentation.

The second part of *Working Paper 14, A programme in Mathematics for the Young School Leaver,*[12] provided an outline of suggestions for appropriate course content for a large proportion of the secondary school population. However, Floyd first made the valid point that a serious change in content and in the approach to teaching required that teachers should have access to supportive in-service training. His argument was underpinned by the recommendations of a Report published by the Joint Mathematical Council in June 1965[13] which were later endorsed by a Royal Society Conference on the in-service training of teachers of mathematics and science, called in September 1965.[14] Amongst other suggestions, it was proposed that mathematics centres should be set up by LEAs to provide opportunities for teachers to develop their knowledge, and that each Institute of Education should set up an advisory unit to help provide in-service training programmes in mathematics.

Floyd was influenced in his thinking by a visit to Crown Woods Comprehensive School in South East London,[15] where a lively programme of mathematics was being offered to pupils across a range of abilities. Subsequently, he suggested that studies should target new applications of mathematics and different facets of a mathematical topic: for example, the history of weights and measures; the mathematics in nature, such as growth and food conversion rates; the importance of the dimensions of the 'Golden Section'; the construction of simple logical circuits; the use of binary mathematics; the measurement of speed and of uniform and accelerated motion; betting and gaming, and the mathematics of rocketry and orbitry. It was recommended that many of these topics could be developed within the framework of a CSE Mode I, Mode II or Mode III examination. Two educators of the time gave evidence that developing a mode III syllabus leading to examination was of considerable significance for teachers, in that it gave them both ownership of a programme and a positive view of their role in devising and implementing it.

An interesting feature of the text and the accompanying illustrations within the Report was the introduction of a number of flow charts. These are commonplace today, but were just being introduced into the mathematics world in the 1960s. Philip Floyd provided five flow charts, the first developing and linking a broad range of suggestions and the remainder showing how individual mathematical topics could be developed and linked. By way of example, two charts entitled *Number Appreciation*[16] and *Experimental Probability*[17] respectively, now follow. Both would be useful to teachers in showing how the main topic could be subdivided into a large number of subtopics and how links could be established between subtopics.

Fig 5.1 Number Appreciation

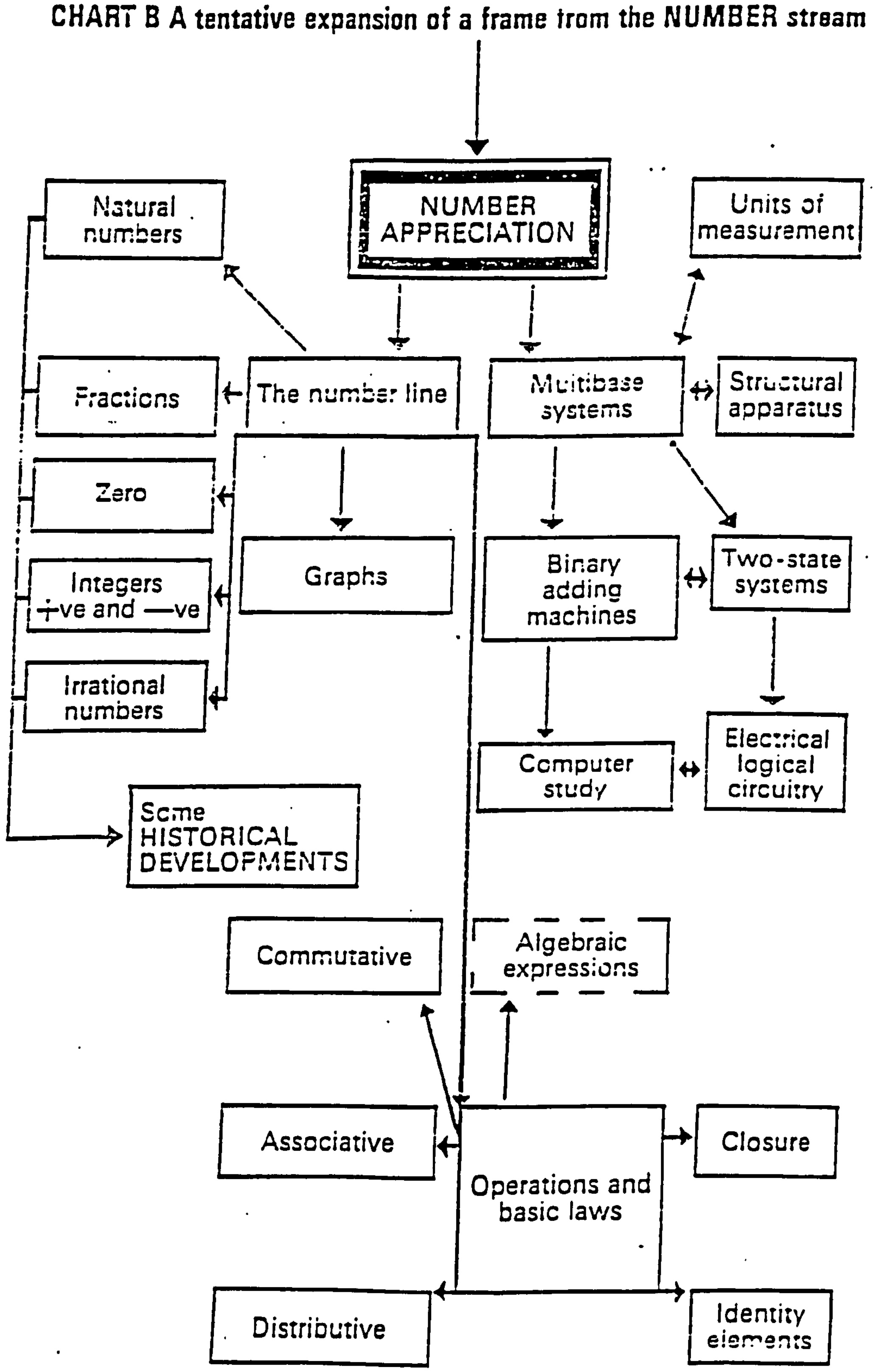
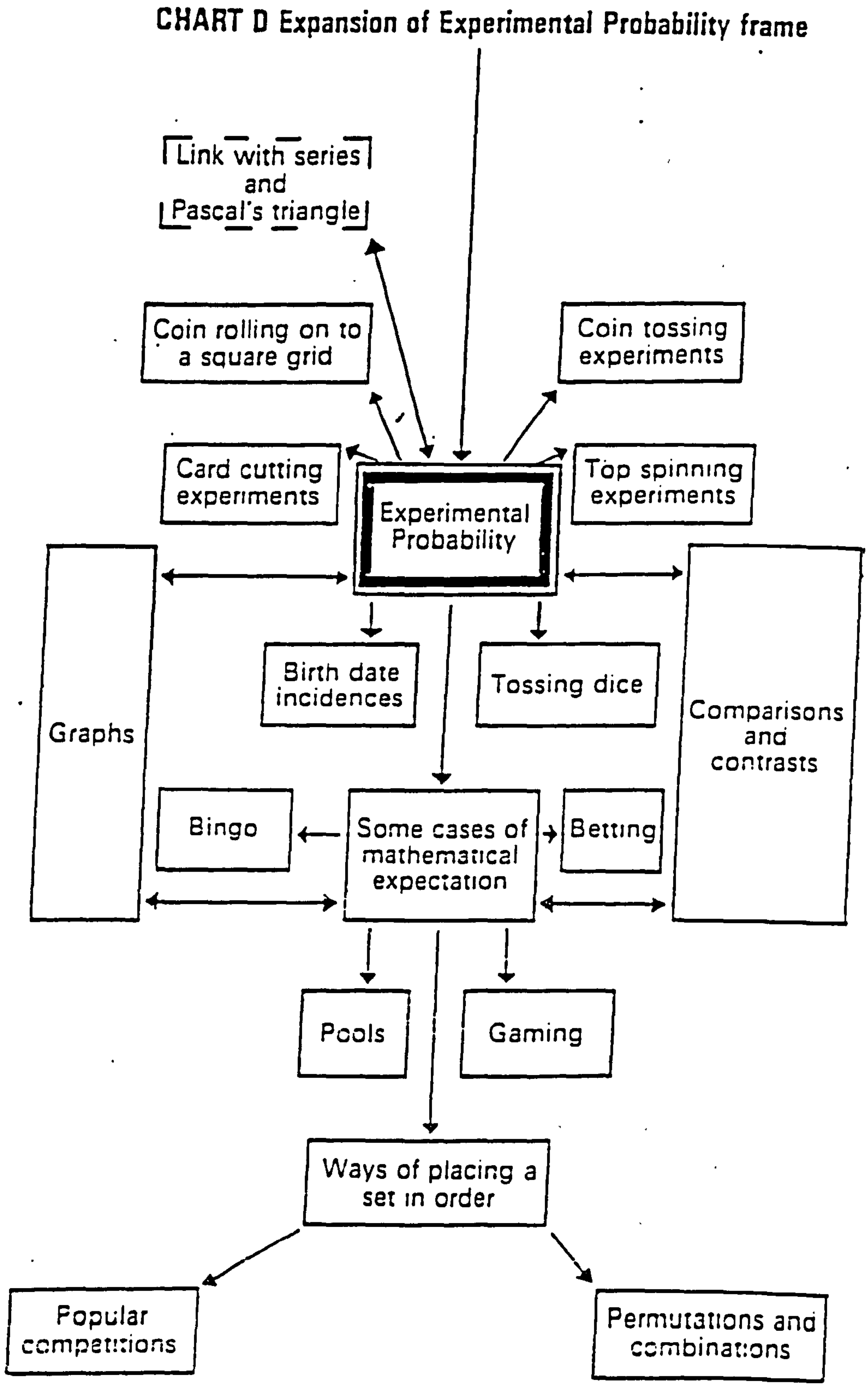


Fig 5.2 Experimental Probability



Philip Floyd concluded by summarising the main issues in mathematics education for this ability range. Pupils should have an appreciation of order and pattern in mathematics within the 'man-made' world. Each student should have experiences of mathematical situations which would encourage powers of judgement and the exercise of imagination. This would be of more use than the mere acquisition of a mass of facts and a collection of what could be redundant mathematical skills and techniques. Essentially, each pupil should have an understanding of a number of basic mathematical concepts and knowledge of a range of useful mathematical techniques which would permit him or her to play a part as a responsible and intelligent member of society. Mathematical studies, combined with knowledge gained from other areas of the curriculum and applied in situations relevant to the interests of the pupils and the world in which they live, should form a substantial part of work in school.

The Project and its materials

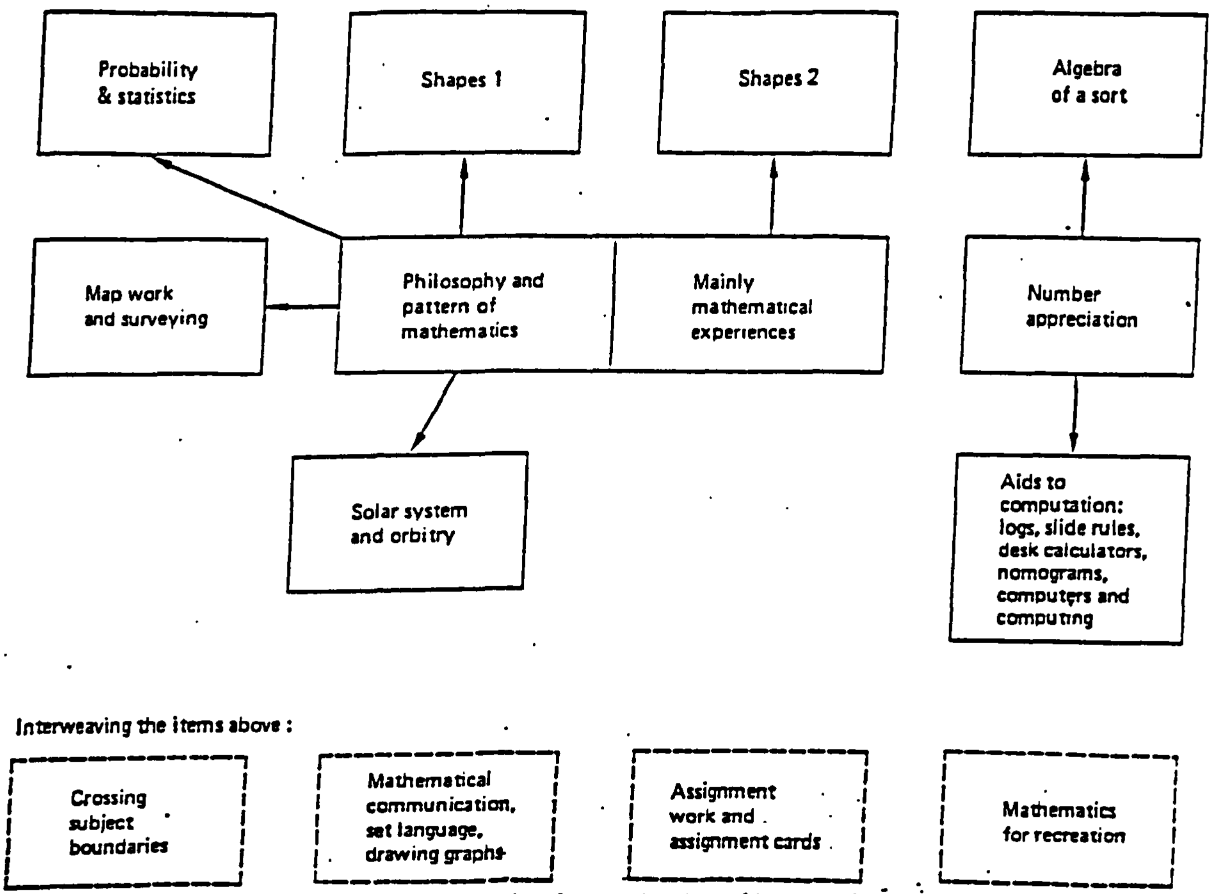
In 1967, following the publication of *Working Paper 14*, a Schools Council funded Project in secondary school mathematics was set up, entitled 'Mathematics for the Majority'. It was initially given a grant of £83,000 to support its work up to 1970, and later, a further amount of £24,000 to cover its extension to 1972. It was based at Exeter University Institute of Education with Philip Floyd as Director. It enabled many of the ideas in the Working Paper to be developed in depth. The Project aimed to help teachers construct courses for pupils of average or below average ability and to provide 'some insight into the processes that lie behind the use of mathematics as the language of science and as a source of interest in everyday things.'[18] This was in contrast to the Schools Mathematics Project, which, at least initially, focused on the needs of pupils of selective schools, and where the essential task of the writers was to modify an already existing 'traditional' content syllabus to incorporate modern mathematics. There was adequate recognition of the need for special provision for those designated at that time as 'remedial' pupils, although the diet was somewhat arid and restricted until Brenda Denvir wrote, and the Schools Council published, *Working Paper 72: Low Attainers in Mathematics 5 - 16: Policy and Practice in Schools,*[19] which contained a host of ideas for their mathematical education.

The Mathematics for the Majority Project was unusual in that it set out to provide opportunities for pupils of average or below average ability to study topics which could have been thought to be beyond their competence to understand, for example, space travel and probability. From the author's experience, such proposed content differed considerably from the typical curriculum diet in mathematics for the 'C' 'D' and 'E' streams in many secondary schools of the 1950s and 1960s. This was generally repetitive and confined to explanations of, and practice exercises in, the use of arithmetical techniques, together with a small amount of algebra involving simplification of terms and the solution of equations, some geometrical constructions and an introduction to trigonometry through, for example, a discussion of heights and shadow lengths.

Initial decisions had profound consequences for the outcome of the Project. As in the case of the Nuffield Primary mathematics project, Teachers' guides were used as the vehicle to convey ideas for the development of topics to teachers and to assist them in preparing their own materials. No textbooks or pupils' materials were written. The thrust of the guides was practical rather than academic, and group work and discussion were encouraged. A conscious effort was made to blur the boundaries between subjects.[20]

The Director of the Project appointed a team of two full-time and three part-time writers and undertook to prepare the series of Teachers' guides. Duties were allocated to the writers and an initial work plan for the production of the guides drawn up. A copy follows.[21]

Fig 5.3 The plan for the production of the MMP Teachers guides



Mathematics for the Majority: work plan for production of teachers' guides

The Project identified 26 pre-pilot schools in six LEAs situated close to the Project headquarters, 87 pilot schools in 23 LEAs and 378 associate schools in 80 LEAs, the second and third category schools being situated across the breadth of England and Wales. The plan was to ask heads of mathematics departments in the pre-pilot schools to read, and then to give a critical opinion of, the first draft of each guide. After receiving this appraisal and making any adaptations which were thought desirable, the guides, in loose leaf form, were to be sent to the pilot schools for trialing with pupils for up to two terms. Upon receipt of reports from these schools, modifications would be made, and the final version of the guides would be produced.

The Project produced sets of pre- and post- test tasks to assess the extent of pupil understanding of the material in the guides; pupils were interviewed by college tutors to gauge their awareness of the mathematical ideas underlying the practical ideas suggested by the Project. Additionally, interviews were held with teachers, focusing on difficulties related to the proposed methodology of implementing the materials.

Some 62 third and fourth year secondary school classes in 36 pilot schools were selected for more detailed case studies, which involved the use of a National Foundation for Educational Research basic mathematical knowledge test, attitude tests, intelligence quotient measures, reading ability assessments and the identification of personality characteristics.

A news sheet was produced by the Project and issued at approximately six monthly intervals. Visits to the pre-pilot and pilot schools were made by members of the small Project team and liaison was established with LEA subject advisers. College of education lecturers and university tutors, some of whom were appointed as 'liaison officers' to arrange regional programmes and conferences, maintained a link with the vast number of associate schools, although this contact was minimal and in some cases non existent.

Almost immediately after starting its work, the Project began to experience problems of logistics and communication. The feedback from the pre-pilot schools was slow to emerge and pilot schools had to wait over two years before they could begin trials. By then some classes of young school leavers allocated for experiment had dispersed and some of the teachers had moved on to other schools. The Project itself was extended, but such was the delay in the completion of the guides that the contracts of some of the writers - the number of whom had declined to three in 1972 - had terminated before the books were published in their final form.[22]

The Teachers' guides

The Project relied on Teachers' guides to carry its message for curriculum reform in mathematics to teachers working in schools. A total of 15 guides was published; the full list of titles is as follows:

Algebra of a Sort[23]
Assignment Systems[24]
Crossing Subject Boundaries[25]
From Counting to Calculating[26]
Geometry for Enjoyment[27]
Luck and Judgement[28]
Machines Mechanisms and Mathematics[29]
Mathematical Experience[30]
Mathematical Pattern[31]
Mathematics from Outdoors[32]
Number Appreciation[33]
Some Routes through the Guides[34]
Some Simple Functions[35]
Space Travel and Mathematics 1[36]
Space Travel and Mathematics 2[37]

Philip Floyd, Director of the Project, was responsible for two of the 15 Teachers' guides produced by the Project, and, additionally, contributed to *Some Routes through the Guides.* Colleagues who assisted in writing other materials came from a wide spectrum of educational activity. D S Feilker was head of the mathematics department in the Inner London Education Authority Crown Woods comprehensive school whilst at the same time being responsible for activities in a specialist teachers' centre in south east London. HMI T M Murray-Rust wrote two of the Teachers' guides. John Parker was a teacher of mathematics at Riddlesdown School, while Jo Stevens taught at Crown Woods School and lectured at Whitelands College of Education before becoming an inspector with the Surrey LEA and ultimately Director of Education in Oxfordshire. Peter Kaner, who became the Director of the Mathematics for the Majority Continuation Project, was the evaluator of materials for the main Project.

As with the Nuffield Primary Mathematics Project Teachers' guides, there was an attempt by the writers to justify the new curriculum ideas. In retrospect however, the overall tone seemed rather timid and speculative. A possible explanation stems from the fact that the new approach to mathematics learning, which involved greater participation by pupils in lessons, with much less emphasis on undertaking practice exercises, had hardly had time to become even a subject for debate in secondary schools at this time, in marked contrast to the situation in many primary schools

Although published in 1974, rather later than other guides, *Some Routes through the Guides* was a key volume in that it both summarised the essential philosophy and practice of the Project and gave a substantial overview of the focus and content of each Teachers' guide. Floyd described typical objectives for a mathematics curriculum for pupils of average and below average ability, suggesting how mathematics courses for pupils might be implemented and fitted into an academic year. Chapter one, the introduction, was short. It reflected contemporary concerns about control of curriculum which had surfaced earlier in the previous decade at the time of the formation of the Schools Council and made clear that the Project's suggestions for curriculum change were not prescriptive, strongly maintaining that the responsibility for choosing a curriculum for pupils rested squarely on the shoulders of teachers and other educators. Reference was made to the work of the newly formed Mathematics for the Majority Continuation Project, which had begun before the main project had finished. Based on the ideas of the parent Project, the

Continuation Project aimed to produce packs of materials for pupil use, again focusing on the needs of average or below average ability pupils in the 13 to 16 age range. Its inception could be seen as an acknowledgement of the comparatively limited value of Teachers' guides in influencing change as compared to the more direct influence of the teaching materials which can be put in the hands of teachers and pupils.

Chapter two gave a succinct review of the thrust of each of the guides, whilst chapter three of *Some Routes through the Guides* addressed the purpose and objectives of a mathematics curriculum and listed a number of policies which a school would need to establish to serve the needs of average and below average ability pupils. Floyd described six objectives which he thought that teachers must have in choosing a curriculum:

> to use mathematics as an instrument in the personal and social development of the individual pupil;
>
> to achieve and maintain a critical view of existing procedures in mathematics education and to institute changes when and where they are appropriate.
>
> to be conversant with, and practised in, a variety of approaches to meet the varied requirements of the individual pupil.
>
> to seek out and acquire materials, apparatus and artefacts which lead to mathematics learning and which are conducive to mathematical thinking
>
> to construct balanced courses where facets of mathematics are each fairly and meaningfully represented. The facets were identified as concerned with utility, culture, pattern and structure, language, aesthetic value and ways of thinking and working.
>
> to preserve an element of continuity in the mathematics education of the pupil.

These objectives can be seen as part philosophical and part practical. They reflected new thinking in the late 1950s and 1960s which suggested that almost all pupils could achieve at a higher level, given a new approach to curriculum and to its teaching and learning. The steady abolition of the 11+ examination, coupled with the establishment of comprehensive schools, and the wide range of opportunities which were being offered, supported this expectation. Realistically, however, bearing in mind the intellectual capacity of the target group, it was likely that only a few of the objectives listed above could be fully realised by the majority. Floyd's elaboration of the first objective, for example, spoke of the need for adaptability, discrimination, judgement, perseverance, accuracy, clear thinking, creativity and development of aesthetic appreciation. Personal teaching experience at the time left an impression that, laudable though these aims were, few pupils could do more than succeed at a very basic level in these contexts.

A policy for the implementation of a meaningful curriculum would, according to the guide's author, require practical and logistic support, for example in setting up a mathematics room or centre in each school together with allocating a fair share of the time of specialist mathematics staff and resources towards meeting the needs of average and below average ability pupils. Consideration ought to be given to promoting flexible teaching and learning programmes. This last suggestion was an interesting one - that the mathematics curriculum should be designed as a series of small elective courses - almost the forerunner of the modular arrangement popular in the 1990s.

Chapter four, entitled 'Some mathematics courses', developed ideas for study by pupils of a number of units or modules which broadly served the objectives which are described above. Floyd then combined these into a balanced course. The suggestions were well documented and examples given of how the programme could be phased over three terms of a school year.

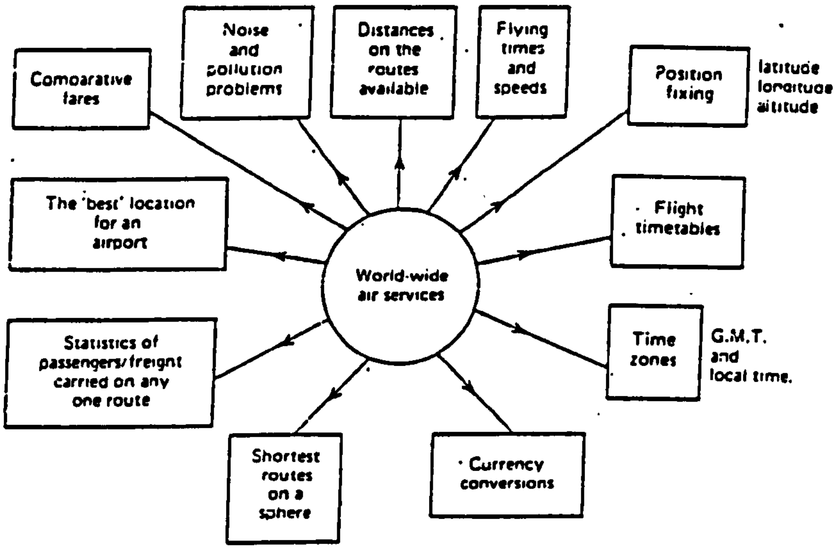
A diagrammatic representation of a typical development entitled 'World wide air services' is shown in the chart which follows.[38] It showed how a range of linked studies concerning fares, location of an airport, noise and pollution, timetables, flying times and speeds, can be addressed.

Fig 5.4 Studies linked to world wide air services

Example D

Example D approaches the situation from a different angle. An agreed wide study becomes the *starting point*, and whatever short courses prove to be necessary or desirable emanate from the central theme. In such circumstances it is obviously of mathematical value to choose a topic which contains or suggests such further developments, rather than one in which mathematics is sparsely represented.

Let us assume that the agreed study is G 11: World-wide air services.



Once the general theme is introduced and discussed, any one of the topics in the outer zone could be the subject of short intensive study. Mathematical skills and techniques thus appear for what they really are, tools for doing a job.

Chapter four concludes with a reassurance from the author that the topics and the methods of working discussed in the chapter and indeed throughout the Teachers' guides, would adequately prepare students for CSE examinations, inevitably an important concern for teachers. In attempting to meet this challenge, Floyd set out, in a short index at the end of chapter two, details of links which could be made between a topic, for example the Fibonacci series, and its coverage in Teachers' guides - in this case in *Number Appreciation* and *Mathematical Pattern.* Similar links were established between elements of the syllabuses of the CSE examination boards and topics in the Teachers' guides.

Chapters five and six focused on books for both pupil and teacher which would support this approach to studies and on commercially produced materials. Chapter seven suggested some issues which those teachers following the Mathematics for the Majority Project approach might want to discuss; for example, classroom and pupil organisation, evaluation of the pupil task results and the role of the teacher in developing these programmes with pupils.

Some Routes through the Guides was similar in approach to *I do and I Understand,*[39] the introductory guide produced by the Nuffield Primary Mathematics Project. Both discussed the broad aims and objectives of a mathematics curriculum; both stressed the importance of recognising the incidence of pattern and structure in mathematics and of its aesthetic representation; both focused on the importance of language and on the utilitarian and cultural value of mathematics; both were key volumes in underpinning the thrust of the developmental ideas associated with each Project.

The 15 Teachers' guides were divided into four subsets by Philip Floyd:

Five books which dealt with fundamental mathematical ideas

From Counting to Calculating

Number Appreciation

Some Simple Functions

Geometry for Enjoyment

Algebra of a Sort

Five books which focused on mathematics in action

Machines, Mechanisms and Mathematics

Mathematics from Outdoors

Space Travel and Mathematics 1

Space Travel and Mathematics 2

Luck and Judgement

Two books which emphasized the pervasiveness and universality of mathematics

Crossing Subject Boundaries

Mathematical Pattern

Three books which highlighted ways and means of organising and presenting the subject

Mathematical Experience

Assignment Systems

Some Routes through the Guides

A brief overview of the guides follows; as an exemplar, the last in each subset, (except *Some Routes through the Guides* which has already been discussed at length), will be reviewed in depth.

In the first subset, *From Counting to Calculating* discussed the arithmetic content which was appropriate for the targeted ability range, identified problems which pupils often find in calculating, and suggested strategies for remediation. Of particular interest was author Philip Floyd's recommendation that pupils be allowed to use aids, such as a digital calculating machine, to free them to address more exciting and worthwhile mathematical pursuits. This proposal touched on a dilemma which continues to be the subject of debate today - to what extent pupils should simply be given electronic tools to obtain an answer without necessarily having an understanding of the basic technique, or whether the latter is an essential prerequisite for all pupils.

Number Appreciation, written by K C Bonnaud, focused on a study of number systems and their application, and in particular reviewed the importance of the commutative, associative and distributive laws. *Some Simple Functions*, written by E T Norris, concentrated on relationships in mathematics, and provided teachers with an insight into the meaning of functions, as exemplified in the topics of direct proportion and exponential growth. A practical, as opposed to a conventional academic approach, was stressed by David Feilker, the author of *Geometry for Enjoyment*, based on activities using three and two dimensional shapes which could present opportunities for the solution of mathematical problems or for the investigation of situations which illustrated mathematics in action.

The last volume in this subset, *Algebra of a Sort*, was written by E T Norris; it was made up of three chapters, the second and third of which respectively developed ideas about induction and generalisation, and about understanding formulae, which had been introduced in the first chapter. The latter began by posing the question 'what is algebra?', stressing the importance of developing generalisations and relationships, firstly in words and later in symbols, from the mass of facts and experiences which pupils met both in and out of school. Inductive and deductive reasoning were compared, where in the former the truth of the assertion depends on the increasing weight of evidence provided by a large number of favourable instances found, whilst the latter resorted to logical inference in moving from one step to the next.

Throughout this book explanations invariably utilised examples in arithmetic before generalising to an algebraic form. For example:

$1 \times 3 + 1 = 2^2$

$2 \times 4 + 1 = 3^2$

....

can be generalised to $n \times (n + 2) + 1 = (n + 1)^2$

It was noted that the transition to the generalisation would not be easy for many of the pupils targeted in this Project.There would, in any case, have to be an intermediate stage when, through discussion, some statement in words about the relationship would emerge. The author believed that developmental activity of this kind would promote a deeper understanding of the meaning and use of a symbolic statement or formula and would in any case contribute to the intellectual maturing of pupils.

Following an introductory section, seven topics were suggested as important requirements of any algebra syllabus:

conventions and signs used in symbolic notation
meaning and use of indices
substitution
collection of terms and simplification of expressions
use and removal of brackets
factors
solution of equations

In chapter two the author expanded upon the topic of generalisations from patterns. Examples were chosen from geometry and arithmetic, as in the following:

Number of sides of a polygon	3	4	5	6	....
Number of triangles found	1	2	3	4	....
Sum of angles, (in right angles)	2	4	6	8	....

This relationship was first expressed in words - 'the number of right angles is twice the number of triangles' and then symbolically as 'the number of right angles in all the angles of a polygon of n sides is 2 (n - 2)'. The author continued to develop representations of relationships, twelve in total, throughout the chapter. He reviewed, for example, difference finding in number series, Pythagorean triples, square and triangular number series, and the relationship generated by the intersections of straight lines on a plane.

Chapter three was concerned with formulae, and how these could evolve from practical classroom experience, using appropriate equipment. For example - a very simple case - the area of a rectangle can be found by multiplying its length by its breadth, leading to the symbolic representation A = l x b. The author of the guide addressed in detail topics such as indices, brackets, factorisation, simple, linear, simultaneous and quadratic equations, all of which can require the determination and use of formulae. As before, examples with numbers were used first, before proceeding to a generalised expression.

Algebra of a Sort was principally directed towards improving the mathematical education of the teacher. The text was dense and the examples repetitive. Non-specialist teachers would have found the reading hard and time consuming and, although some suggestions were made for activities which the ultimate target group of pupils could undertake, it is doubtful whether this guide would have enabled teachers to present a particularly enlightened view of algebra. Equally, it is perhaps indicative that the author of this guide remarked that pupils may only be able to take a few simple steps in determining a generalisation or in preparing and using a formula; in other words, their horizon was limited.

The books in the second subset, which examined mathematics in action, were potentially of considerable interest to teachers and pupils since they focused on applications of mathematics. For example, *Machines, Mechanisms and Mathematics*, written by A B Bolt and J E Hiscocks, centred on simple mechanisms which are met with in daily life, such as those used in operating a car jack, the gears of a bicycle or a washing machine. The authors made the point that the shape of objects within a mechanism was highly significant, being designed to fulfil a specific purpose. The book provided an account of the mathematical principles underlying their operation. *Mathematics from Outdoors,* written by E T Norris, was mainly concerned with the concepts and techniques of simple surveying, fixing positions, and navigation and addressed subjects such as triangulation, similarity and trigonometry.

In the late 1960s and early 1970s space travel was very much in its infancy and it was therefore a powerful challenge for the author, J H D Parker, to suggest, in *Space Travel and Mathematics 1* and *2*, ideas which could illustrate the link between mathematics and space travel for teachers, and indirectly for pupils of average or below average ability. Parker held the view that basic ideas relating to this subject were within the competence of the lay mind. The two books, the second being a sequel to the first, contained a mixture of narrative, such as, for example, an imaginary journey to the moon, and details of experiments capable of being performed by most pupils in the classroom with simple apparatus. Among a catholic range of chapter headings were: short biographies of rocketry specialists, gravitation, escape speeds and weightlessness, and electronic computers and flow diagrams. Consideration was given to the scale and representation of time and distance in space, together with the problems of interplanetary travel and re-entry into the earth's atmosphere.

The last volume in this subset, *Luck and Judgement,* by Jo Stevens, was very similar in content and approach to the Nuffield Project's Teachers' guide entitled *Probability and Statistics.*[40] Both advocated practical work with pupils using coins and dice and focused on data collection and frequency counts. Both offered suggestions about how topics might be taught, although *Luck and Judgement* was more definitive and offered a more comprehensive explanation to teachers of the concept of probability. It was easy to read and the suggestions for pupil activity could be put into practice without difficulty. The guide was divided into two parts. The first, which was longer at 89 pages, consisted of five chapters. After a preliminary discussion in chapter one, a range of classroom activities was examined in chapter two, followed by notes on graphical representation of data in chapter three. Chapters four and five described 32 experiments which pupils could carry out; each was followed by the author's observations and suggestions for class discussion which could lead to conclusions about expected and observed outcomes.

Part two, which was relatively short at 44 pages, contained seven chapters. The author cautioned that, because of intellectual demands, some of the tasks which were suggested would present problems for pupils. Chapter six, for example, focused on permutations and combinations and their symbolic representation- difficult for some students to comprehend - but important because of applications in sports competitions. Chapter seven addressed questionnaires and information storage and described in some detail the use of the punched card as an example of a coding system for the latter. In chapter eight, the author discussed the principles involved in sampling and random sampling, and suggested five experiments which pupils could undertake to illustrate the topic. Chapter nine introduced, in simple terms, the notion of calculating probabilities and expressing the result as a vulgar fraction. The following two chapters, 10 and 11, addressed a number of related topics in the context of comparing statistics - measures of central tendency, the mode, median, and arithmetic, geometric and harmonic mean - together with measures of dispersion - range, quartiles, mean and standard deviation, the Binomial and Poisson distributions and the idea of correlation. Chapter 12 provided suggestions for follow-up work with pupils.

Appendix one listed books for both pupils and teachers which would be useful in studying probability and statistics. Appendix two set out useful information for teachers on the methodology of introducing practical activities for the targeted ability range, illustrating examples of work cards which gave simple and precise instructions for pupils, whilst Appendix three focused on solutions to problems related to the presentation and marking of pupils' written work.

The books in the third subset emphasized the pervasiveness and universality of mathematics. In *Crossing Subject Boundaries,* J H D Parker described how mathematics can permeate work with pupils in diverse situations across a number of subjects. The chapter headings, a selection of which follows, gave an indication of the areas where the author clearly showed opportunities to establish links: environmental studies, orienteering, music, geography, history, science, art and sport

The last book in the third subset, *Mathematical Pattern*, was written by T M Murray-Rust and divided into a preface and six chapters. The purpose of the guide was to help teachers and pupils appreciate that there was a strong element of patterning in all branches of mathematics. To underline this, the author linked his text to the materials in the other guides - in *Number Appreciation, Luck and Judgement, Algebra of a Sort, Machines, Mechanisms and Mathematics,* and *Mathematics from Outdoors.*

Chapters two to six focused on pattern in number, pattern in shapes, pattern in graphical representation, pattern in statistics, and probability and chance. A short book list for the use of teachers and pupils in working on these topics was offered at the end of the guide.

The author made it clear that he was writing this guide for teachers in order to improve their mathematical education, rather than suggesting activities for pupils. The guide, however, exhibited the same problems that attended *Algebra of a Sort.* The text was dense, and although broken up by diagrams, drawings and some graphs, resorted rather too frequently to rhetorical questioning. The subject matter was often, of itself, interesting, but explanations and comments tended to be overlong. Since much of the content, which was addressed in summary form in this book, was explored much more thoroughly in previously published Teachers' guides, it seems difficult to understand the purpose of writing of *Mathematical Pattern* towards the termination of the Project.

The fourth subset of guides highlighted ways and means of organising and presenting the subject. *Mathematical Experience*, the first of the guides to be published, was written by members of the Project team. The early part of the book discussed why mathematics should be learned before focusing on appropriate content and how it might be taught. The authors suggest that a teacher should be seen as a guide, philosopher and friend to pupils rather than simply an instructor which was an unusual idea in the eyes of most teachers of the day. The guide compared 'old' and 'new' mathematics content and endeavoured to summarize the requirements of a suitable mathematics curriculum for pupils under the headings of mathematical numeracy and literacy. Seven case studies were recorded in part two, written by teachers and based on their experiences in the classroom in promoting the new approach to teaching mathematics.

Assignment Systems, written by T M Murray-Rust, discussed new methods of presenting tasks to pupils, particularly in relation to the creation of assignment cards, newly introduced at this time. Topics such as closed and open-ended tasks (that is those which were carried out precisely in accordance with a series of printed directions as compared with those which encouraged action according to the interpretation by the student), group and individual activities, and the time scales involved in using assignment cards, were discussed. Details of 46 assignment cards were recorded as exemplars of this approach. A recurring theme of this guide was an examination of ways of promoting a close personal involvement by the pupil in his or her mathematics learning, and there was also discussion of the relevant problem of pupils' reading competence in the context of the use of assignment cards.

Some Routes through the Guides, the last of this subset, has already been reviewed in depth.

In summary, the Director of the Project ably demonstrated his understanding of the needs of pupils capable of average or below average attainment. He showed how these needs might be met, in the hope of generating much greater mathematical understanding within this group. Several members of his team were able, in their writing of the Teachers' guides, to suggest sensible, rewarding and often exciting activities which young students could pursue in class. However, whilst the content of all the guides could be considered mathematically sound, some failed seriously to address the basic requirement of the Project - to help teachers construct appropriate courses for pupils of this ability. Such a variation in style would seem to point to a lack of cohesion in the writing team in regard to the aims of the Project and to a lack of overall editorial control of the material by the Director. It is possible that both these defects were a by-product of the logistical and communication problems which beset the Project almost from its inception.

The Impact of the Project

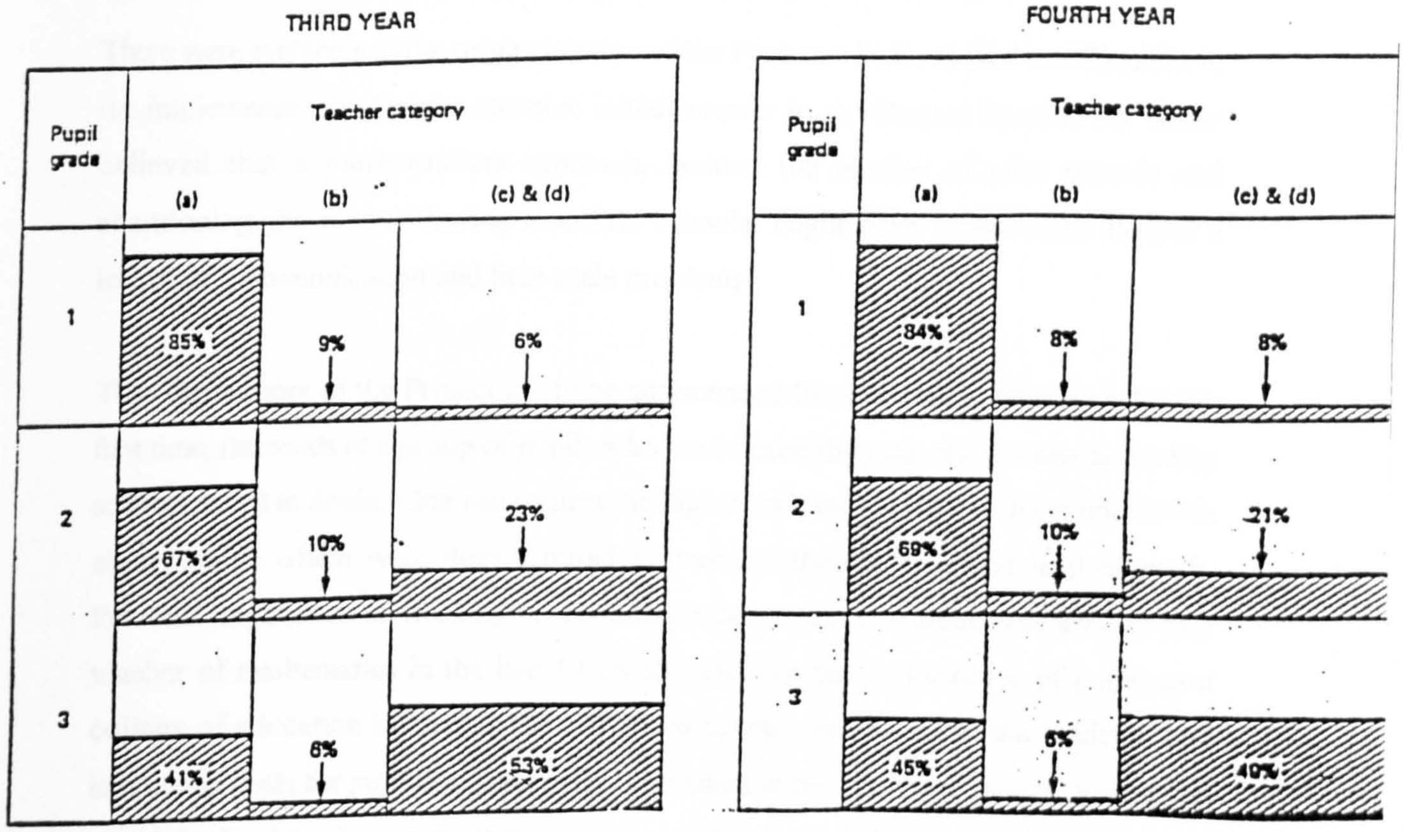
In the late 1960s and early 1970s, the growth of comprehensive schools, CSE examinations and the introduction of some mixed ability teaching brought fresh calls for new syllabuses and teaching materials suitable for a wider ability range. The Mathematics for the Majority Project represented a response to this demand which was targeted on pupils who were 13 to 16 years old and of average or below average ability. The Director of the Project, Philip Floyd, was employed in a college of education; it is argued elsewhere in this study that it was in the teacher training field that intense discussion about curriculum innovation in a number of subjects took place in the 1960s. Schools Council *Working Paper 14*,[41] authored by Floyd, provided many suggestions for a change in approach to mathematics teaching and learning. The exciting ideas he expressed in this Report and the encouragement he gave to the other writers of the Project Teachers' guides, signalled a proposal for major alterations in syllabus content and in teaching methods for what was, in fact, the vast majority of pupils in secondary schools, who heretofore had been offered a restricted and often arid mathematical diet.

The topic coverage of the 15 Teachers' guides was comprehensive and ambitious; endeavours were made by the authors not only to make the subject matter applicable to everyday life but also to make some of the more traditional academic mathematics, such as algebra and geometry, more practical and understandable. The inclusion of *Space Travel and Mathematics 1* and *2* as Teachers' guides was remarkable, bearing in mind the ability range of the targeted pupil groups and the fact that space technology was in its infancy. Equally, investigations which crossed subject boundaries constituted a bold step in the early 1970s, when individual subject teaching in the classroom with a closed door was the norm. The limited introduction of 'modern' mathematics and its symbolism, together with the promotion of group and investigatory activities, albeit within a rather more formal framework of procedures than advocated by the Nuffield Primary Mathematics Project, represented a revolutionary step forward in mathematics teaching at secondary level at the time.

The Mathematics for the Majority Project began publishing its guides in 1970, as Price writes 'in the second wave of Projects',[42] somewhat later than the first guides of the Nuffield Project in 1967. By this time, some of the euphoria attached to curriculum change was beginning to recede, and the reactionary comments of the *Black Papers*[43] were beginning to emerge. It is worth examining whether this Project ever had sufficient momentum to convince teachers that there was merit in taking up its ideas seriously in order to enhance the long term mathematical education of their pupils. There were essentially two problems which militated against, and ultimately prevented, the acquisition of that momentum. Firstly, no textbooks or pupil materials were written, and hence teachers involved in the Project were required to generate their own programme of study. They then had to provide appropriate materials, work cards or sheets for pupils to undertake activities. The task was made more difficult because many pupils had seen themselves as failures in mathematics over a number of years and thus had a poor attitude to the subject. Secondly, many of the teachers who were responsible for teaching mathematics in schools were non-specialists. They accepted that their lack of mathematical knowledge made it difficult to participate in Project activities before they had acquired sufficient mathematical background of each topic to be able to supervise pupils' studies confidently. The resolution of both these problems required time, a commodity which a busy teacher did not have in abundance.[44]

Peter Kaner, who later became the Director of the Mathematics for the Majority Continuation Project, was the evaluator of the parent Project. His report, based on a survey of 100 schools within the Project, formed a chapter in *Evaluation in Curriculum Development: Twelve Case Studies.*[45] He made a number of observations which were relevant to an examination of the impact of the Mathematics for the Majority Project. In one facet of his enquiry he categorised teachers into four groups: (a) those possessing specialist mathematics qualifications, (b) those with another specialism but teaching mathematics full-time, (c) those with another specialism but teaching part-time in the mathematics department, (d) other teachers - possibly the headteacher or a remedial teacher. He divided the third and fourth year secondary school pupils into three groupings, (1) academic, (2) average, (3) below average, and found that over half the 'below average' students were taught mathematics by non-specialist teachers, whereas 85% and 84% of academic pupils were taught by mathematics specialists in years three and four respectively. A copy of the chart giving details of allocation of teachers to pupil groups follows.[46] It is apparent that the majority of the student members of the very cohort which the Project hoped to target were largely deprived of regular contact with the specialist help which could have gone a long way towards improving their mathematical awareness.

Fig 5.5 Allocation of teachers to pupil groups



Kaner argued that an improvement in the standard of mathematical education was largely dependent on training and assistance that could be given to the non-specialist and part-time teachers. It was envisaged that the Project liaison officers, who were principally college of education lecturers or LEA advisers, would undertake this work, but the evaluation case study indicated that it had been difficult to implement this support programme. Kaner noted a particular problem in this context in that it was not considered politic, at that time, to measure teachers' mathematical attainment level or teaching skill. This information, had it been obtained, would have enabled training to be more precisely targeted.

There were problems in the original design of the Project which resulted in difficulties in its implementation. Despite massive initial interest in the Project by schools, Kaner believed that a more ruthless approach, limiting the number of pilot schools and abandoning the idea of having associate schools, might have lessened the Project's logistical, communication and time scale problems.

That the authors of the Project are to be commended for addressing, effectively for the first time, the needs of a group of pupils who constituted the majority in many secondary schools, is not in doubt. One can respect the high hopes and aspirations for pupils in this ability range which were demonstrated by most of the guide writers in their work. Personal experience of working in secondary modern and comprehensive schools as a teacher of mathematics in the late 1950s and viewing the performance of pupils as a college of education lecturer in the 1960s, led to the conclusion that the academic and intellectual goals for pupils' achievement, as implied in the Teachers' guides, were set at too high a level for the vast majority to succeed. But it would be too simplistic merely to conclude that success eluded these students because most were intellectually incapable of attempting to scale the heights which the Project proposed for them. Clearly, some of the material in the guides was too difficult for a busy teacher to assimilate quickly and then to translate into tasks in which pupils would be able to show success. Indeed, in evidence, three educators expressed the view that projects of this time, including MMP, faltered because too much additional work was required of teachers to implement the new programmes.

There were other factors which militated against the success of the Project.The cost to schools of a set of the Teachers' guides was seen by two educators as a deterrent to their use. The fact that the Project relied principally on the Teachers' guides to carry its message detracted from its impact and was suggested by some commentators as a reason for its relative failure, whilst naive management control exacerbated problems associated with the production of materials and the organisation of support procedures for teachers. The guides provided many suggestions for activities with pupils, but there was, according to one of the Project writers, no philosophy underpinning the totality of the writing, nor yet any matching and comprehensive scheme of work which would incorporate the suggested content and methodology into a three or four year curriculum programme. Essentially, the guides presented a large collection of 'tips for teachers', related to a number of topics, which could be utilised in class to a lesser or greater extent according to the inclination of the teacher.

Another contributory factor to the apparent lack of marked effect on practice in schools could have been the absence of a dynamic and influential personality to lead the team, such as Bryan Thwaites, the formidable Director of the SMP Project.The perceived absence of support for the Project by professional mathematicians nationally constituted a substantial hindrance to its success. The Report *Mathematics for the Majority*[47] was published in 1967. Following the establishment of the Project, its materials were produced between 1970 and 1974. Nevertheless, *Mathematics Teaching*, the journal of the Association of Teachers of Mathematics (ATM) did not furnish any review of the Report, nor of the aims and objectives of the Project, between 1967 and 1975. Discussion of individual Teachers' guides was limited during this period to three separate entries in the 'books reviewed' sections. Firstly, in 1971,[48] *Mathematics Experience* received a broadly favourable review, *Assignment Systems* had a very cool reception and *Machines, Mechanisms and Mathematics* had a mixed reception. Secondly, in 1973,[49] *Luck and Judgement* was well received by the reviewer, *Mathematical Pattern* was not favoured while *From Counting to Calculating* showed 'a breath of fresh air'. Finally, in 1974,[50] *Algebra of a Sort* received little or no praise, with the reviewer suggesting that a study of other kinds of algebras would have been more appropriate for children. Issue number 71,[51] published in 1975, noted that the Teachers' guide, *Space Travel & Mathematics, Volume 2*, had been received.

Meetings of the local branches of the Association of Teachers of Mathematics might have been thought an appropriate venue for the spread of information about the Project. In the period under review, the ATM Diary in Issue 45[52] in 1968, advertised a meeting of the Gloucester branch when P J Floyd (the Leader of the Project) was to talk about 'Mathematics for the Majority'. The ATM Diary in Issue 51[53] in 1970, reported that J Hargreaves was to talk about the Project to the North East Branch of the ATM in Newcastle, whilst the Diary in Issue 53,[54] 1970, told readers that Mrs Val Underwood would undertake the same task at the Chichester Teachers' Centre. This evidence suggests that individual branch secretaries took only a minimal interest in publicising the Project.

During this period, *Mathematics Teaching* devoted some 37 column inches to a discussion of the Project's materials, with comments which were, with two notable exceptions, lukewarm, and four column inches to disseminating information about relevant meetings for teachers. In the same period the journal devoted some 109 column inches to a similar discussion on the SMP materials, where comments were supportive, some 59 column inches to the Midlands Mathematical Experiment materials, with particularly supportive comments, and some 68 column inches to the Nuffield Primary Mathematics Project materials, where the comments were warm.

Within the same time interval, the Mathematical Association journal *Mathematics in Schools*[55] devoted some 76 column inches to a discussion of SMP materials and some 33 column inches to the Nuffield Primary Mathematics Project.This evidence suggests that editorial policy reflected a greater professional interest on the part of readers in a secondary school project which addressed the mathematical needs of pupils whose abilities ranged from the average to the most able, and on a high profile primary school project which introduced some revolutionary 'modern mathematics' content.

The Mathematical Association took a number of initiatives over this period which, in theory, could have supported the aims of the Mathematics for the Majority Project. It set up two subcommittees in 1963 and 1965 respectively to review the challenges of teaching in comprehensive schools and the nature of mathematics which might be taught to pupils in the 11 to 16 age range. Neither, however, seemed to have had an early impact.[56] The Mathematical Association appeared to be incapable of producing a report in a relatively short time (it took 17 years to publish the first primary school mathematics report of 1955 and 13 years for the secondary modern mathematics report of 1959)[57] but it ultimately published a report in 1974 entitled *Mathematics 11 to 16* [58] which was comprehensive in its approach and included discussion on new content and revised teaching methods, resources and assessment for pupils in this age range. It appeared, however, that the report was too late for serious consideration in the context of provision for the majority of pupils for 'there was no strong sense of mission in relation to the audience for and purpose of such a report at this time'.[59]

The Mathematics for the Majority Project, with its concentration on the production of Teachers' guides, did not appear to have been successful in its overall aims. It is clear that the need for the production of pupil classroom materials was realised quickly and the Mathematics for the Majority Continuation Project (MMCP), established in 1971, met this demand through the production of teaching packs by groups of teachers, which in the opinion of one educator, were the precursor of the widely used SMILE[60] materials in the next decade and beyond.

However, the evidence of a senior educationalist who wrote for the original Project is significant in the context of the long term effect of its output. In her opinion, although the guides made little impact, the ideas which were expressed by MMP prepared the ground for the next generation of authors in this field. In particular, she believed that the component within the present day National Curriculum for mathematics entitled 'breadth of study', had its origins in the concepts which underpinned the materials set out in the publications of MMP.

The Mathematics for the Majority Project was timely and it promised to cater for a deeply felt need amongst secondary school mathematics teachers and in turn for the majority of their pupils. Unfortunately, the willingness of the Project team to respond to the hugely manifested need expressed by schools contributed to its undoing. Its members were overwhelmed by the tasks they had collectively taken on, a situation made worse by the lack of a tight management structure. However, it needs to be acknowledged that a project which tried to break completely new ground in the teaching of the non-academic pupil would inevitably encounter more difficulties than would be the case in other projects which addressed the needs of abler pupils, for whose curriculum needs there had already been considerable research.[61]

Its over-riding fault was in neglecting to provide a clear strategy for the implementation of its ideas in new mathematics curriculum and methodology of teaching, and this omission pointed up the fallibility of this approach to curriculum reform. But perhaps the most significant factor was identified in the limited measure of support for a project targeted at this particular ability group, even though its members constituted the majority of pupils. It is argued that the Mathematics for the Majority Project was a victim of a top-down approach to school curriculum reform in mathematics, which had favoured meeting the needs of more able pupils. With hindsight, the Cockcroft Report[62] of 1982 wrote:

> We believe...that the changes in the examination system and in the organisation of secondary schools which have taken place in recent years have influenced the teaching of mathematics in ways which have been neither intended nor sufficiently realised. At the present time up to 80% of pupils in secondary schools are following courses leading to examinations whose syllabuses are comparable in extent and conceptual difficulty with those which 20 years ago were followed by only about 25% of pupils. Because... it is the content of O level syllabuses which exerts the greatest influence, it is the pupils whose attainment is average or below who have been most greatly disadvantaged.[63]

Notes.

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2. Schools Council 1965, *Working Paper 2: Raising the school leaving age. A cooperative programme of research and development,* HMSO, London
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13. Joint Mathematical Council 1965, *Report on the In-service Training of Teachers of Mathematics,* Carlton House Terrace, London SW1Y 5AG
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15. Personal communication with Ms Jo Stevens, 22 March 2000
16. Schools Council 1967, *Working Paper 14,* p 28
17. Schools Council 1967, *Working Paper 14,* p 32
18. Schools Council 1976, *Explanatory Paper, MA 13 01, Mathematics for the Majority Project*

19. Schools Council 1982, *Working Paper 72, Low Attainers in mathematics 5 - 16: policy and practice in schools,* Methuen Educational for the Schools Council, London

20. Schools Council 1973, *Evaluation in curriculum development: Twelve Case Studies: papers from the Schools Council's project evaluators on aspects of their work,* Macmillan Education, Basingstoke, pp 128-129

21. Schools Council 1973, p 129

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The following *Teachers' Guides* were written by the Mathematics for the Majority Project and published by Chatto and Windus Educational, St. Albans, for the Schools Council

23. *Algebra of a sort* 1973

24. *Assignment Systems* 1970

25. *Crossing Subject Boundaries* 1974

26. *From Counting to Calculating* 1972

27. *Geometry for Enjoyment* 1973

28. *Luck and Judgement* 1971

29. *Machines Mechanisms and Mathematics* 1970

30. *Mathematical Experience* 1970

31. *Mathematical Pattern* 1971

32. *Mathematics from Outdoors* 1972

33. *Number Appreciation* 1971

34. *Some Routes through the Guides* 1974

35. *Some Simple Functions* 1972

36. *Space Travel and Mathematics* 1 1974

37. *Space Travel and Mathematics* 2 1974

38. *Some Routes through the Guides* 1974, p 38

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43. Cox, B and Dyson, R E (Eds) 1969b, *The Crisis in Education: Black Paper 2*, Critical Quarterly Society, London

44. Schools Council 1973, p 131

45. Schools Council 1973

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47. Schools Council 1967, *Working Paper 14*

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49. *Mathematics Teaching* 1973, 62

50. *Mathematics Teaching* 1974, 68

51. *Mathematics Teaching* 1975, 71

52 *Mathematics Teaching* 1968, 45

53. *Mathematics Teaching* 1970, 51

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Chapter six

THE NUFFIELD FOUNDATION PRIMARY MATHEMATICS PROJECT 1964 - 1972

One of the most important developments which heralded a new approach to mathematics teaching at the primary school level was the establishment in the mid 1960s of the Nuffield Foundation's Primary Mathematics Project. Even in the year 2001, over 30 years later, the description 'Nuffield Maths' remains, not least through the existence in some schools of the residual copies of a comprehensive series of textbooks bearing the same name.[1] A number of projects targeted curriculum change at the secondary school level, two of which are reviewed in this study, but the Nuffield Mathematics Project was the only major initiative which focused on change at the primary school level; the extended length of this chapter, compared with the length of those examining the two secondary school projects, reflects both this factor and the extensive output of the Nuffield Project

The Project produced many Teachers' guides, the general thrust of which reflected contemporary educational thinking. Whether the location of that thinking lay not so much with teachers in classrooms, but rather elsewhere - with educationalists, in, for example, universities, teacher education institutions and local education authority (LEA) advisory services - is examined later in this chapter.

Background

In February 1966, the recently created Schools Council published a document entitled *New Developments in Mathematics Teaching.* [2] This was described, in the preamble, as 'a first progress report on the Joint Schools Council - Nuffield Foundation Project for helping teachers to find out about, discuss amongst themselves, try out and apply - in their own way and in their own classrooms - what is often called the "discovery" approach to mathematics teaching'.

The paper principally focused on changes in approach to mathematics teaching and learning in the primary school which had taken place, and were taking place about the time of the writing of the document. It began, however, by offering a commentary on developments in mathematics teaching at the secondary school level between 1920 and 1960. It was suggested that there had been a steady liberalising of approach over these years, a trend supported by proposals for an alternative syllabus for School Certificate mathematics which were put forward in 1944 at a conference convened under the chairmanship of Dr G B Jeffery.[3]

The paper reviewed some of the forces for change which were at work in the post second world war period, referring first to Professor Jean Piaget in Geneva who had been researching into how children acquire concepts. Piaget wrote on a range of topics. Specifically in the field of mathematics, he published *The Child's Conception of Number,*[4] *The Child's Conception of Geometry*[5] and *The Child's Conception of Space.*[6] His principal findings about the acquisition of concepts centred on the desirability for children to have practical experiences of handling materials, and gave renewed weight to the child-centred philosophies of education such as those emanating from Froebel[7] and Montessori.[8]

It was in the infant schools that new developments in the approach to mathematics curriculum (rather than merely arithmetic) were first seen. Indeed it was not uncommon in the 1960s to see some pupils of this age being involved in elementary mechanics problems relating, for example, to balancing, to friction and to gradients, but with a stress on a 'discovery' or 'finding out' approach, stimulated by an initial question to a group of children from the teacher, such as, 'what happens if.....?' This method, which was often initiated by individual teachers and invariably against the accepted wisdom of the day, which tended to force pupils towards a premature involvement in learning computational skills, did however pave the way towards a 'new look' for mathematics work throughout the primary school. HMI Miss L D Adams inspired many teachers through her supportive writing in *A Background to Primary School Mathematics,*[9] the contents of which anticipated much that was written in a major report of the Mathematical Association, published in 1956, entitled *The Teaching of Mathematics in the Primary School,*[10] in which constructive play and experimentation[11] was encouraged, and the use of mathematical apparatus recommended. In her Presidential address to the Mathematical Association in 1960, Miss Adams argued that practical mathematical experiences were of great importance for young children; she stressed the need for them to acquire mathematical understanding, rather than merely learning to manipulate arithmetical techniques.[12]

The need for children to learn by experiment gradually gained credence and permeated the whole primary school curriculum, although in the mathematical context, the study and practice of arithmetical techniques in junior schools continued largely unabated, principally because of the need to prepare children for the 11+ examination which still existed in the 1960s. In summary, some infant school teachers appeared to be willing to promote a hands-on approach for pupils, with a smaller stress on the computational aspects of arithmetic, whereas most junior school teachers clearly reversed these emphases. As a consequence, it is argued that pupils of the 1960s received a less rounded curriculum in mathematics, especially in the junior school. From personal observation, the gradual abolition of the 11+ examination by LEAs around 1970, encouraged many teachers to widen the scope of the mathematics curriculum and to change their methods of teaching.

In many infant and junior schools, mathematics, or more accurately, arithmetic, was taught by teachers who had little expertise in, or liking for the subject. Despite the regularly noted appearance in infant schools of exciting initiatives in a mathematics context in the late 1950s and early 1960s, most teachers followed a conventional approach of firstly introducing a topic to pupils, for example the arithmetical technique of adding numbers within the range of 10 to 100 with a focus on place value, and then requiring children to undertake practice exercises, often of considerable length.

Against this background an attempt was made in the late 1950s to accelerate the pace of reform and in particular to increase the confidence of primary school teachers in the mathematics field. In 1959, HMI Miss Edith Biggs was commissioned by her Chief Inspector to mobilise all available resources to spread more liberal ideas about the learning of mathematics by primary school children. She organised and ran many short training courses for primary school headteachers and teachers, inspectors, advisers, a small number of secondary school teachers and some administrators, in all parts of the United Kingdom with the active support of local education authorities. From personal experience of involvement in these and similar courses it is known that they were extremely popular, not least because the teachers, like the pupils who were ultimately the target of this approach, joined in practical sessions where their own mathematical learning was increased and where they could discuss the significance of what they were doing with a colleague.

Despite their undoubted success it was apparent to the Ministry of Education and to HMI that the courses were insufficient in themselves to generate change. They were 'taster' courses; teachers would return to school with some practical ideas for work with children and some indication of a justification both for a new methodology of teaching and for new content. They would not, however, have any coherent strategy for curriculum change. It was seen as important for teachers to have continuing help in translating new thinking into practice and it was the quest for new forms of effective action which led to the establishment of local teachers' centres and of the Nuffield Primary Mathematics Project.

The rest of this chapter is divided into three sections. The first explores the origins and development of the Nuffield Primary Mathematics Project, identifies the people involved in its work, and the educational base from which their ideas came. The second examines a sample of the materials which were produced by the Project between 1965 and 1972 and the third section provides an assessment of the overall impact of the Project.

Origins and development of the Project

Early History

The suggestion for the establishment of a primary school mathematics project originated with Her Majesty's Inspectorate, and in particular, with three members - senior inspector Robert Morris, a talented mathematician who was to become the joint secretary of the

Schools Council in 1964, senior inspector A P Rollett, a distinguished mathematician closely associated with the work of the Mathematical Association, and Edith Biggs.

The Nuffield Foundation agreed to finance a project, working in collaboration with interested parties such as the Ministry of Education, the LEAs and colleges of education, whilst the Ministry took responsibility for developing nation-wide in-service training courses associated with the initiative. LEAs provided in service training centres for teachers, where they could meet and work regularly. The Nuffield Foundation funded the production of a series of Teachers' guides, but in keeping with the philosophy of the times, it was understood that the guides would be seen as 'advisory' in nature, and in no sense prescriptive. The Annual Reports of the Nuffield Foundation from 1962 to 1967[13] reflected the Foundation's growing interest in curriculum reform over this period. A sum of £250,000 was set aside in 1962 to develop programmes in this context, including in primary science and mathematics. Both the 1963 and 1964 Annual Reports spoke of supporting the development of school curriculum and of teaching materials and the 1964 Report noted the formation of the Nuffield Primary Mathematics Project. Significantly, and reflecting contemporary ideas associated with new teaching methodologies and content, the 1964 Report looked to an extension of widespread experimentation in new techniques in primary mathematics leading to the exploration of unifying ideas in 'modern mathematics' at an early age, whilst the 1965 Report underlined the need for practical mathematical experiences for pupils, contributing to the acquisition of abstract concepts.

In 1964, the Foundation made a grant of £140,000 to cover the first four years of the Project's work, followed by a further grant of £66,300 in 1968 to offset costs in the next three years,[14] even though, in 1965, the Foundation had signalled its intention to withdraw from the field of curriculum renewal, consequent upon the establishment of the Schools Council.

A parallel project focusing on primary science education was established by the Nuffield Foundation in May 1964, led by Mr E R Wastnege from Kesteven College of Education. There was seen to be much common ground between the challenges involved in reforming the teaching of both science and mathematics. A decision to cater for children up to the age of 13 was taken, in acknowledgement of the need for changes in the approach to the teaching of both subjects at primary level to carry over to the lower secondary school level. In mathematics, this decision clearly acknowledged the developments which were evolving at secondary school level in the early 1960s, through, for example, the work leading to the establishment of the School Mathematics Project and the Contemporary School Mathematics Project, and particularly in relation to the 'new' or 'modern' curriculum content.

The Nuffield Foundation commissioned a small team, led by Dr Geoffrey Matthews, to be responsible for the compilation and issue of teaching materials. The choice of Geoffrey Matthews as Director of the Project may appear strange at first consideration. He had no primary school teaching experience; indeed all his teaching had been in the secondary selective school sector. He had not attended HMI Edith Biggs' practical exposure courses. In his favour, however, was the fact that he was known to be an outstanding mathematician and was responsible for sending a high number of pupils to Cambridge University from his school, St. Dunstan's in Catford, to read mathematics. The Oxford and Cambridge Board ultimately accepted his *Contemporary School Mathematics (CSM)*[15] scheme as a preparation for a GCE 'O' level examination, parallelling the experience of Bryan Thwaites in authenticating the School Mathematics Project materials. Matthews was known to move in circles in which both the officers of the Nuffield Foundation and HMI had personal and professional contacts.[16] He was much influenced by the new developments in university mathematics and was close to HMI Arthur Rollett, an influential member of the Mathematical Association, and had attended conferences on his behalf in Paris and Budapest.

The first writing team was chosen from some 12 individuals, whose names were mainly suggested by Edith Biggs, and who were invited to Nuffield Lodge, the headquarters of the Nuffield Foundation, to give advice on the proposed primary mathematics project.[17] For the most part, the team was composed of practising teachers or those who had had recent teaching experience at the primary school level. The names of the members of the team are given in Appendix C to this thesis. The Consultative Committee, representative of a range of mathematical interests, was set up at the same time. The members were chosen by Tony Becher, a member of the Nuffield Foundation, Senior HMI Robert Morris, formerly joint secretary of the Ministry of Education's Curriculum Study Group and Dr Geoffrey Matthews.[18] Their names can be found in Appendix D.

Geoffrey Matthews, the Organiser of the Nuffield Primary Mathematics Project from 1964 to 1972 and a member of its Consultative Committee, was born in 1917, educated at Marlborough College and Jesus College, Cambridge, where he took a degree in mathematics in 1938. He obtained a Ph.D. at the University of London in 1959 with a thesis entitled 'Contributions to the Theory of Infinite Matrices'. After war service he began teaching at Haberdashers Aske's Hampstead School in 1945, before being appointed Deputy Head and Head of Mathematics at St. Dunstan's College, Catford, in 1950. Matthews was Shell Professor of mathematics education based at the Centre for Science and Mathematics Education, Chelsea College, University of London from 1968 until 1977 and President of the MathematicalAssociation, 1977 - 78.

There were five other members of the team. Miss Barbara Mogford had formerly been Deputy Headteacher of an infant school in Bristol before becoming a Lecturer in Early Childhood Education at Salisbury Teacher Training College and then at Goldsmiths' College, University of London. Miss Brenda Jackson was seconded to the Project from her post as Deputy Headteacher of a primary school in the east end of London; similarly Jim Boucher had been a class teacher in a junior school in Blackpool and subsequently became the headteacher of Devonshire Junior School in the same town. George Corston was seconded to the Project from his post as Headteacher of a junior school in Southall, Middlesex while Harold Fletcher, a dynamic character with persuasive skills and subsequently the leading author of a popular textbook series of the 1970s for use in primary schools entitled *Mathematics for Schools*,[19] was an inspector of schools in Staffordshire.

The 14 strong Consultative Committee contained a number of distinguished members. Professor W H Cockcroft was born in 1923, educated at Keighley Boys' Grammar School and Balliol College Oxford where he gained his M.A. and later a D.Phil. From 1949 to 1956 he was Assistant Lecturer at Aberdeen University and from 1956 to 1961 Lecturer and later Reader at Southampton University; he was appointed Professor at Hull University in 1961. Cockcroft chaired the Consultative Committee of the Nuffield Primary Mathematics Project from 1963 to 1971 and later, from 1978 to 1982, the Committee to consider the teaching of mathematics in school in England and Wales which led to the writing of the *Report*[20] which bears his name. He was the Chair of the Schools Council's mathematics subject committee from 1964 until 1974, when his place was taken by D A Quadling, mathematics tutor at the Cambridge University Institute of Education and an original member of the School Mathematics Project.[21]

Professor Jack Wrigley was born in 1928, educated at Oldham High School and Manchester University where he obtained a B.Sc. in mathematics and subsequently an M.Ed. He obtained his Ph.D. at Queens University, Belfast, where he had taken the post of Lecturer in Education in 1951. He was Lecturer in the teaching of mathematics at the Institute of Education, University of London from 1958 to 1962 before his translation in 1963 to the University of Southampton, taking the post of Deputy Vice-Chancellor and Professor of Education. In 1967 he moved to Reading University to become Professor of Curriculum Resources and Development, whilst at the same time being Director of Studies at the Schools Council from 1967 to 1975. He was the research member of the Ministry of Education's Curriculum Study Group (CSG), which preceded the establishment of the Schools Council.

Robert Lyness, born in 1909, was a distinguished contributor to the work of the Consultative Committee. Educated at Uppingham School and Brasenose College Oxford, he gained a B.A. in mathematics and P.P.E. His teaching experience was at Bromsgrove School, Repton School and Bristol Grammar School. In 1946 he was appointed HMI and was made Senior HMI in 1963, a post he held until 1972, during the period of innovation and rapid development of ideas pertinent to the teaching and learning of mathematics.

Brian Young, knighted in 1976, was the Director of the Nuffield Foundation from 1964 to 1970; his dynamism and imagination during a particularly formative period in mathematics curriculum development were of considerable significance for the impact of the Project in the country as a whole. Born in 1922, he was educated at Eton and King's College, Cambridge, taking first class honours in parts one and two of the Classical Tripos and winning the Porson Prize in 1946. Prior to his time at the Nuffield Foundation he had been Headmaster of Charterhouse School from 1952 to 1964.

The Project team, led by Dr Geoffrey Matthews and supported by an eminent consultative committee, thus represented a powerful collective force in addressing the challenge of mathematics curriculum renewal at the primary stage.

<u>The Selection of Experimental Areas.</u>

In June 1964 the Ministry of Education sent a circular letter to all LEAs in England and Wales inviting them to participate either in the Nuffield Primary Mathematics or the Nuffield Primary Science projects, or of both if they wished. It was hoped that a small number of pilot areas, nine for mathematics, eight for science, could be set up to test Project materials, with four areas to test both sets of materials. The Ministry of Education organised and financed central courses for the training of the Project's designated local leaders.

One hundred of the 145 LEAs expressed interest in joining the projects in one form or another. The Schools Council was established in October 1964 and one of the first acts of the Steering Committee concerned with primary education was to endorse the selection of what proved to be 14 pilot areas, representative of a broad cross section of national education conditions, which were to participate in the two projects. A list of the LEAs and the specific geographical areas within them which were selected for the pilot experiment is given as Appendix E. Some 44 areas (Devon, Dorset, Nottingham and Sheffield, for example), had already embarked on experimental work and were invited to become 'consultative' areas for the Project.[22] The areas selected to take part in the pilot stage began using the new trial materials in the autumn of 1965 and subsequently provided feedback to the Project. For LEAs which had volunteered for participation but had not been selected, a second phase of the Project was planned along similar lines, involving 78 areas, to begin in autumn 1966.

The Primary Education Steering Committee of the Schools Council also endorsed the publication of HMI Edith Biggs' *Curriculum Bulletin No.1, Mathematics in Primary Schools.*[23] The writing of this *Bulletin* was conceived in the earliest days of the planning of the Project as another way of reinforcing in-service training for the primary school teacher, by providing, in an accessible and usable form, suggestions for the application of new approaches to mathematics teaching in the classroom. Such was the national interest that the first print run of the *Bulletin* in 1965 of 20,000 copies was exhausted in three months, and there were two further reprintings during the same year.

Concurrently the Schools Council and the newly designated Department for Education and Science, successor to the Ministry of Education, jointly sponsored a training film called *Maths Alive* designed to help teachers attending in-service training courses to visualise the effect of implementing new approaches to mathematics teaching in their own classrooms. It depicted children in primary schools in London, Derbyshire and Nottingham discovering for themselves how much mathematics there was in their own surroundings, both inside and outside school.

<u>The Project: Preparation and Progress 1964/65</u>

The first formulation of Project aims provided a classic example of the research and development approach to curriculum change - 'The object of the ... Project is to produce a contemporary course for children from 5 to 13. This will be designed to help them connect together many aspects of the world around them, to introduce them gradually to the processes of abstract thinking and to foster in them a critical, logical, but also creative, turn of mind'.[24] There are clear similarities with the initial aim of the secondary stage Schools Mathematics Project- 'to develop a school syllabus and teaching methods....which will reflect the true nature of mathematics and its up-to-date usages more adequately and vitally, than ...... do the traditional syllabuses'.[25]

The Nuffield Primary Mathematics Project team started work in September 1964. A plan for the writing of the guides by this team, (its composition changed in later years), was devised and this is reproduced as Appendix F to this study. Essentially, there were three categories of training materials: Teachers' guides, Weaving guides and Check-up guides. The Teachers' guides cover three main topics: Computation and Structure (denoted on the book covers by a black circle), Shape and Size (denoted on the book covers by a black inverted equilateral triangle) and Graphs leading to Algebra (denoted on the book covers by a black square). In the Teachers' guides the development of mathematics was seen as a spiral, with the same concept being met many times and illustrated in a different way on each occasion. This approach accorded well with the views of Jerome Bruner who championed the implementation of a spiral curriculum, asserting that 'a curriculum, as it develops, should revisit these basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them'.[26] Bruner believed that any subject can be taught to any child at any age in some form that is honest.[27] Each guide contained a number of teaching suggestions and most some illustrations of children's work.

The Weaving guides were single concept books which gave detailed instructions or information about a particular subject. Six were produced during the lifetime of the Project, for example *Desk Calculators* (1967),[28] *Logic* (1972)[29] and *Probability and Statistics* (1969).[30]

The Project was greatly concerned with assessment of children's understanding of mathematics and mathematical concepts. A series of guides under the general title of 'Check-ups' was produced by the Project in cooperation with Professor Piaget at the Institut des Sciences de l' Education in Geneva.

The first publication by the Project, however, was a separate Teachers' guide entitled *I* *do and I understand,*[31] which essentially set the parameters for the Project's approach to mathematics teaching and learning. This emerged from the printers in June 1967, whilst the other guides followed later in 1967 and in subsequent years.

The Project commissioned a film entitled *I do and I understand* illustrating new approaches to primary mathematics teaching; it was made in the school where one of the team members, Jim Boucher, was based. British Petroleum underwrote the cost of making the film.

In October 1964, the Schools Council became the sponsor of the Nuffield Primary Mathematics Project; it did not, however, provide financial assistance. An in-service training programme, organised by the Schools Council for the Project was pushed ahead with speed, the first course being held in Cambridge in December 1964. Staff for the courses were drawn from HM Inspectorate, the Nuffield Project team and teachers; LEAs facilitated attendance of teachers, administrators and inspectors who were to be concerned with organising the promotion of new approaches to mathematics teaching. The LEAs also nominated two or three intended 'pilot area' organisers to attend. Following the practice and philosophy of Miss Biggs' courses, participants were put into the same situation as children in the classroom applying 'discovery' approaches to their investigations; they worked in groups - matching another strong thrust of the recommended methodology; sufficient time was given to experiment with simple materials and to draw conclusions from the researches, whilst opportunity was provided to consider the practicalities of introducing these methods into the classroom. Two further courses for teachers from other pilot areas were held in 1965. Each participating LEA was asked to nominate one infant and one junior school teacher to provide a direct link between the Nuffield team, the Schools Council staff and individual schools in the trial areas.

Most importantly, LEA officers and teachers from the consultative areas and some teachers who were selected as leaders on the initial training courses were given responsibility for running local in-service training courses at teachers' centres, including centres in the second phase areas. The notion of seeking and obtaining mutual help from within the teaching profession for servicing the growing needs of in-service training was a significant development in teacher education in this country.

The provision of a teachers' centre by an LEA was a condition of participation in the pilot scheme and after the December 1964 course, the 13 LEAs involved in the trial of the materials found sites for the centres and began to equip and furnish them, a task all but completed by the summer of 1965. These centres, whilst at this time specifically concerned with the improvement of mathematics and science teaching, represented a first step which ultimately led to the creation of permanent in-service training centres throughout the country, often with expanded facilities and concerned with all aspects of the curriculum. Thus, it was this particular focus which triggered an entirely new concept in support for teachers, a development which has been replicated almost worldwide since 1965.

Project Materials

This section reviews the main thrust of the first book published by the Project, *I do and I understand* and a sample of the Teachers' guides, the Weaving guides, the Check-up guides and other material. It comments on their significance in the context of mathematics curriculum development and of contemporary suggestions for changes in the methodology of teaching; it also appraises the appearance and presentation of the guides.

<u>The First Volume</u>

I do and I understand,[32] of 62 pages and in landscape format, was published in 1967; it was dedicated to Professor Jean Piaget.The title was said to be the last line of a Chinese proverb, the complete version of which is as follows: -

I hear and I forget
I see and I remember
I do and I understand

These statements, which seemed to reflect common experience, underlined the philosophy of the approach to learning of the Nuffield Primary Mathematics Project

The book began by inviting the reader to consider why mathematics was necessary, comparing the needs of Victorian times with those of 1967; there was still the requirement to perform computation speedily and accurately but now a more potent need had emerged - for people who can assess situations and can formulate and solve problems. The book stressed the link with science, more specifically in the common areas of experimentation, postulating, hypothesising and communication. Its major emphasis was on how to learn - and not on what to teach. The argument was advanced that if mathematical understanding was to take place, children needed the opportunity to handle materials, to experiment and to draw conclusions before they attempted to deal with abstractions and operations in mathematics. The text drew heavily on the contribution of Jean Piaget, who postulated the existence of mental structures of increasing complexity and differentiation which children developed as a consequence of experience and experimentation.

I do and I understand dealt with the practical implications for teachers and children of pursuing a 'discovery' approach in schools. Sections of the book addressed problems of organisation, both for the school generally and within the classroom, in order to accommodate the new ways of working; consideration was given to how the environment might be used in this context and how assessment, evaluation and record keeping of progress by pupils could be managed in the new milieu in which teachers and children worked. The change from a situation where a test yielded 'marks out of ten', in which assessment was thought to be easy, to one where a whole range of investigatory activities was being carried out by a large number of pupils at the same time, was perceived as posing a serious problem for teachers. To answer this challenge, it was suggested that a form of written assessment or profile of each child's progress was made by the teacher, parallelled by the completion of record cards by both pupil and teacher which listed the number and type of assignments undertaken. The results from traditional attainment tests, which could provide useful evidence of progress, could be added to accumulated records concerning interest, attitude and achievement and to the data obtained from individual 'check-up' tests involving concept formation. This endeavour on the part of the Nuffield

Primary Mathematics Project represented the first tentative approach to the development of more comprehensive ways of assessing and evaluating progress and understanding. Inevitably, however, these tasks served to increase the workload of the teacher.

I do and I understand provided a substantial introduction to the philosophy of the Nuffield Primary Mathematics Project. It was important in that it put forward constructive ideas and strategies, focusing on new methodologies of teaching and on modern mathematics content, at a time when the majority of teachers saw mathematics (and arithmetic) as a very formal subject to be addressed in the primary school in terms of 'sums' and 'problems' and later, at secondary level, principally as an intellectual, rather than a practical exercise.

The Teachers' guides

The three main titles within the category of Teachers' guides - (i) Computation and Structure, (ii) Shape and Size and (iii) Graphs leading to Algebra - were descriptors of elements which could be seen as an alternative way of expressing, in extreme summary form, a traditional syllabus for work in mathematics at the primary school and at the lower secondary school levels. However the similarity ended there because the method of approaching topics and indeed some of the content was quite different from the conventional. There was, for example, a lengthy treatment of the significance of different kinds of number - natural and counting numbers, integers, rational numbers. The authors provided a brief history of the measurement of length, weight, capacity, volume, time, and of money measures, and gave a rich variety of information about how these developed and achieved their present day degree of sophistication.

(i) *Computation and Structure*

All but the first of the five volumes in the 'Computation and Structure' subset used the identical title - that is *Computation and Structure*. By way of sample, the first, entitled *Mathematics Begins*[33] and the later *Computation and Structure 5*, [34] will be appraised in terms of the topics each offered and the manner of their presentation.

Mathematics Begins addressed the needs of children in their first few years at school; it suggested, and extensively illustrated, a range of desirable mathematical experiences for children under four broad headings: continuous and discontinuous/discrete materials, together with conservation of those items; space, shape and size; matching, ordering, classifying and measuring; number words and symbols.

In *Mathematics Begins* and indeed in the next of the subset, *Computation and Structure 2*,[35] the more formal side of mathematical recording and practice was not seen to be justified, largely on the grounds that children needed first to experience and handle materials in many situations in order to conceptualise relationships and understand elementary processes in manipulating numbers and data. Throughout, however, the importance of the use of appropriate language in communicating information was stressed.

Significantly, modern mathematics terminology and practice were illustrated early in *Mathematics Begins,* in relation to 'sets'. The introduction was facilitated through the technique of sorting. 'Subset' and 'partitioning' were also demonstrated, whilst there were many examples of 'mappings'. The concept of the 'ordered pair' was developed. Even at this early stage, set 'intersection' and 'inclusion' and the 'union of sets' were discussed, as was the 'Venn Diagram'. A wide variety of suggestions was made for teachers to help children gain an understanding of these mathematical terms and their usage. The major emphases were on the diagrammatic representation of a relationship, on the use of new symbolism and terminology and relevant descriptive language, with virtually nothing of traditional recording and computation.

The book concluded with an appendix which looked at reflexive, symmetrical and transitive properties, topics which would probably have been difficult for many primary school teachers of the day to assimilate, given the limited mathematics education of the majority.

Computation and Structure 5[36] targeted the needs of older pupils. It addressed the following topics: addition of decimals, rational numbers and their ordering, equivalent fractions, addition, subtraction, multiplication and division of fractions, multiplication and division of decimal fractions, percentage fractions, reciprocals and inverses.

Suggestions to facilitate learning about the addition of decimals followed a fairly traditional path, using one tenth inch squared paper to illustrate one tenth and one hundredth and thus the decimal equivalent of 0.1 and 0.01. The significance of the decimal point was stressed as was 'place value'; examples of addition and subtraction of decimal numbers were shown. Rational numbers and equivalent fractions were dealt with at the same time, invariably using the vehicle of the 'ordered pair'. For example, in developing the table of three, the following pairs emerge: (1,3), (2,6), (3,9) ....; all these could be converted into the rational number one over three. The need to obtain the lowest common multiple in order accurately to generate equivalent fractions was emphasised. It was suggested that a 'fraction board' be constructed in order to illustrate these procedures. The number line which had been used to illustrate natural numbers and integers was utilised to position the simpler rational numbers, both positive and negative. The ordering of these numbers, using the inequalities symbols, was discussed, as were the terms 'reciprocal' and 'inverse'.

Throughout this book, considerable stress was laid on the need to estimate the answer to a problem before proceeding to the operation, to avoid, for example, the result of 2½ x 3⅓ being expressed as 80⅓, or some other variation, when it should be 8⅓.

The topic of division of common fractions was preceded by a section which reviewed sharing (or partitioning) and repeated subtraction (or quotition), the two aspects of division. Vigorous attempts were made to illustrate ways of explaining division of fractions which did not involve merely using the rule: 'turn the second fraction upside down and multiply'. Three approaches were proposed, all of which were justified mathematically, but which would require a degree of sophistication fully to comprehend.

The study of equivalence of common fractions was linked to previous work in this book on decimal fractions in order to facilitate the expression of a simple fraction in decimal terms. Under the subheading of multiplication and division of decimal fractions, the need for pupils to estimate an answer in the first instance was again stressed. Sensible estimation of the result of 4 x 2.6 gave a result of approximately 10, not 100. More complex and more difficult to comprehend for pupils was the answer to a multiplication of two decimal fractions such as 0.3 and 0.2, that is 0.06, a smaller number. This might appear to be unexpected and the book dealt with this kind of problem by suggesting changing the decimal numbers to common fractions, thus 0.3 = 3/10 and 0.2 = 2/10; multiplying the two together gave 6/100 or 0.06.

The suggested basis of the operation for the division of decimal fractions centred on translating the denominator into a whole (i.e. non decimal) number, through the technique of deriving equivalent fractions. For example, 1.28 divided by 0.8 can be written as 12.8 divided by 8 by multiplying both numerator and denominator by 10. Providing the decimal point position in the numerator was respected the accurate answer of 1.6 is obtained.

Finally the equivalence of common fractions, decimal fractions and percentage fractions was addressed in a short two page section of the book, pulling together several different ways of expressing proportions of a whole.

Computation and Structure 5 underlined yet again the purpose of these Teachers' guides - to identify the mathematical concepts which it was felt necessary for children to know and to help teachers overcome the difficulties which pupils experienced in both understanding those concepts and then utilising that knowledge in manipulating and rationalising measures of all kinds. For a generation of teachers who had most likely been taught at school to 'follow the rule' in mathematical operations, some of the explanatory material in this guide, whilst factually correct, could be seen as tiresome, longwinded and convoluted. A certain amount of dedication would have been needed to comprehend the arguments.

(ii) *Shape and Size*

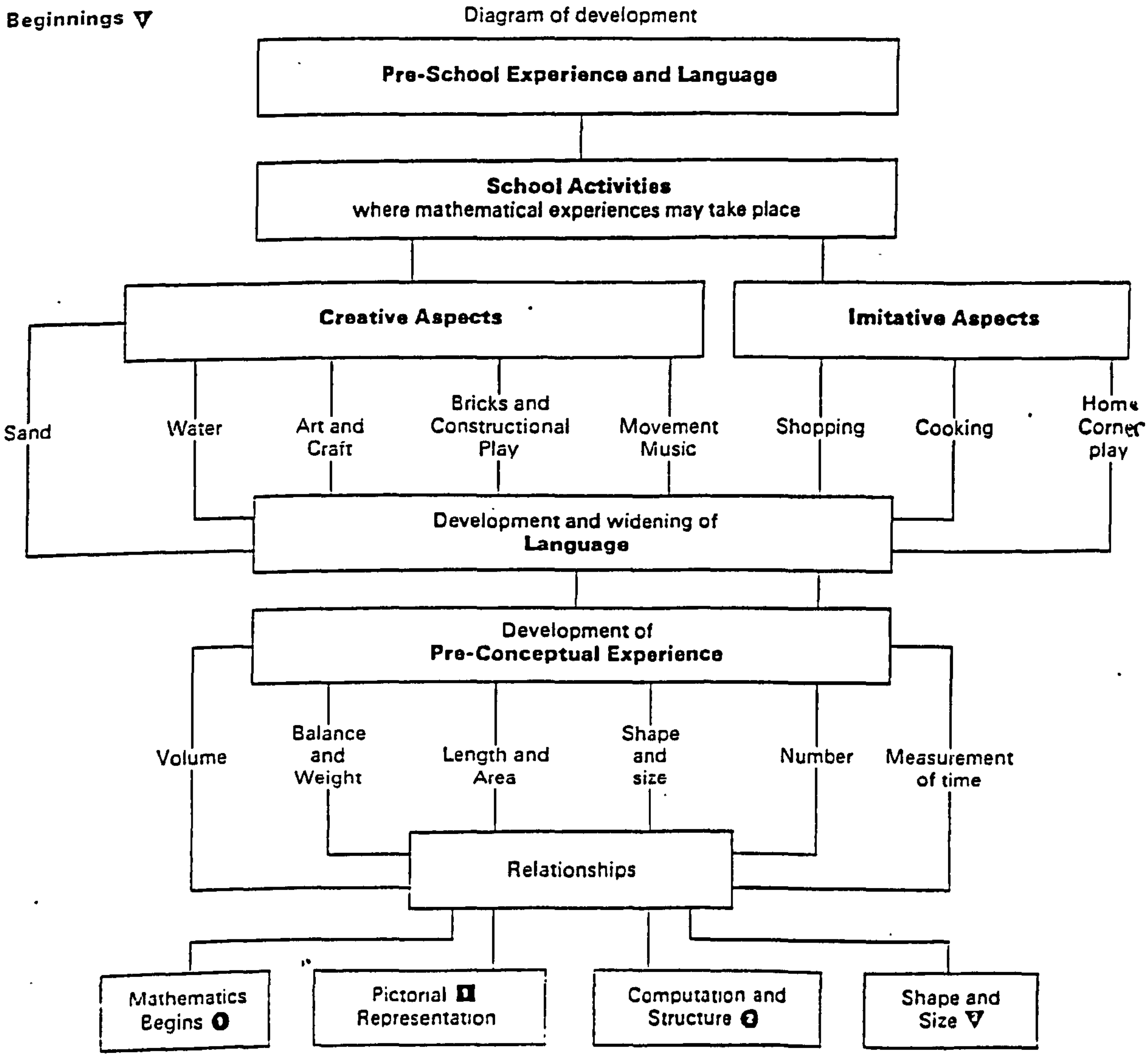
In this subset of Teachers' guides, in which the emphasis is on the practical application of mathematics, two, the first entitled *Beginnings* [37] and the second, *Shape and Size 2*,[38] are sampled.

The introduction to *Beginnings* makes the point that it was parallel in approach to *Mathematics Begins*,[39] the first title in the 'Computation and Structure' subset which developed knowledge of number through a study of relationships. *Beginnings* was also concerned with number but in the different context of measurement emerging from activities involving environmental play and in relation to volume, capacity, length, area, shape, space, time and size. Especially for work with young children, there was, once again, much emphasis on the use of descriptive mathematical language as a facilitator of understanding.

Beginnings focused on children's previous experience and its significance for mathematical development. The first and second sections centred on preschool activities whilst the third discussed creative work, including sand and water play, picture, pattern and model making, needlecrafts, music and movement, physical education and constructional play. The fourth section referred to imitative play - shopping, cooking and the home corner, whilst the fifth looked at children's work. The final section reviewed the development of vocabulary within mathematical experiences, with reference to balance and weight, volume and capacity, length and area, symmetry, shape and size, time and number.

Immediately before page one of *Beginnings* a developmental plan was set out which would have been helpful for a teacher; a copy is shown on the next page. The plan, however, is not sequential, and whilst providing an overview of the topics which the children might study, its implementation would require the teacher to construct his or her own scheme of work.

Fig 6.1 Developmental plan



The importance of capitalising on preschool experience and on the accumulation of a vocabulary to accompany physical activities in a variety of contexts were stressed - using words such as big, little, high, thick, long, for example. The general thrust of the suggestions recommended giving children much opportunity for examining, comparing and measuring objects and for drawing conclusions about them, however crudely they might be expressed at this stage. Comparison of quantities of sand and water was facilitated by the teacher's provision of a variety of containers - cups, buckets, jars, beakers and tins, ultimately leading, with teacher's help, to statements using terms such as 'heavier than', 'the same as', and 'full'. Picture, pattern and model making were regarded as strong agents for promoting an understanding of a variety of mathematical truths and for utilising mathematical terms. Opportunities to measure were readily available in model making - often with non-standard devices such as a length of ribbon or string; equally there were opportunities to develop appropriate descriptive language such as circumference, cylinder, diameter, girth, length and height.

The authors devoted a short subsection to activities for young children in music, movement and physical education which gave rise to the use of incidental mathematical measures and language, such as a 'time beat' in music, to circles and spirals in movement and, in physical education, to spheres, circles, circumference, diameter, in the handling of small and large balls and hoops, together with words such as higher, lower, horizontal, vertical, incline and gradient, in using a climbing frame.

Attention was drawn to the abundant mathematical opportunities in constructional play. Children in the infant school experienced sharing, counting, comparison and matching as they played with two and three dimensional objects; they discovered shapes which fit together easily (tessellation), learnt about area through covering surfaces, and about the meaning of height, width and length. New vocabulary (faces, edges, cubes, for example) could be generated through a refinement and extension of known vocabulary - such as bigger, smaller, larger, thinner, fatter.

Shopping presented opportunities to buy and to sell, to effect a money transaction and to receive change, to assess the number of items in a shop for a certain price and to graph the results in basic format. Following a recipe involved obtaining and weighing ingredients, using capacity measures, understanding instructions and writing up the experience. The text noted the wealth of mathematical vocabulary emerging from these activities, together with a facility to understand and to use measures.

The penultimate subsection of this book, 'Children's work', was 19 pages long and illustrated situations in which mathematics were involved and data could be recorded. There was, for example, a diagram illustrating ships seen in Victoria Dock over 14 weeks, contrasting with an account of the differentiation between wet and dry sand. The drawings and the language of the children are simply expressed, and no great mathematical truths emerge, but the pupils achieved early experience of data recording and of understanding the concept of density.

Copies of these illustrations follow.

Fig 6.2 Recording ships berthed in Victoria Dock

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

Fig 6.3 Differentiating between wet and dry sand

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

The final subsection examined in some detail how mathematical vocabulary and experiences could be extended. It first addressed 'balance and weighing', an understanding of which could ultimately lead to the confident use of standard weights by pupils. Matching and comparing lengths using non standard measures (ribbons or sticks for example) led to an awareness of the vocabulary of comparison - short, shorter, shortest, long, longer, longest; and ultimately to the use of standard units of measurement, involving the tape measure, trundle wheel, metre stick and surveyor's tape. Covering surfaces with identical non-standard materials such as tiles gave an early understanding of the concept of area, which could progress to the use of standard measures of (in the 1960s) the square inch, the square foot, the square yard, later the square metre and square centimetre.

Children's natural or instinctive understanding of symmetry, shape and size in the context of everyday three dimensional life was regarded as important in a number of ways; its development was achieved through observation, through using appropriate vocabulary, through sorting, classifying and ordering, and through recording.

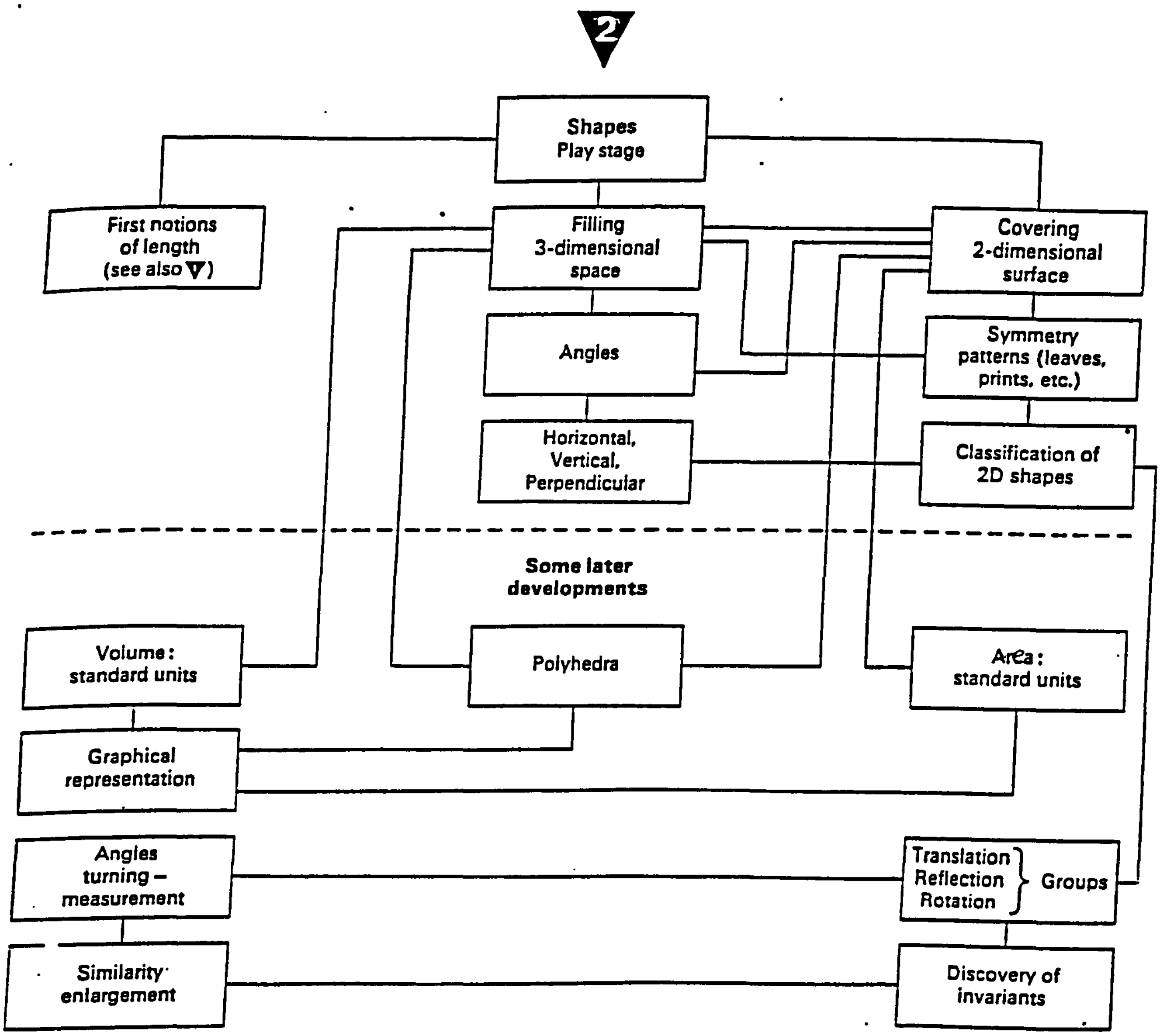
The book concluded by stressing the importance and significance of modern mathematics symbolism in the description of relationships and went on to summarise the arguments in this context which had been advanced in *Beginnings.* It stressed that mathematics for young children derived from, and returned to, a stimulating classroom environment. More controversially for teachers, the authors suggested that the investigatory work by children should not be restricted to a fixed period on the timetable and should spill over into language work and all forms of creative activity. Such an observation, if put into practice, (and the conclusions of the ORACLE Report[40] suggest it was not) would have laid a heavy burden on the organisational and administrative capacity of most teachers.

The topics addressed in *Shape and Size 2* [41] were very similar to those in *Beginnings.* This reflected the opening theme of the Teachers' guides - that the same concept would be met again and again, but on each subsequent occasion at a greater depth and at a higher intellectual level. *Shape and Size 2* concentrated on the following topics: three dimensional space involving volume, capacity and associated shapes; two dimensional shapes, including covering a surface (area) and symmetry. Specific attention was given to right angles, perpendicular and parallel lines.

There were four principal chapters in this book of 102 pages; these were preceded by three short sections entitled 'Introduction', 'Conspectus of Ideas' and 'Children's Activities'. The 'Introduction' concentrated on geometry, taking as examples the word 'angle' which could be seen as a relationship between one plane and another. The thrust of the text encouraged teachers to portray geometry not as a collection of uninspiring facts but as a series of dynamic discoveries in spatial concepts involving shape and size. Teachers were asked, for example, to consider the progression of 'square' numbers (1,4,9,16....) and triangular numbers (1,3,6...) where a link was established between the presentation of number sequences and their resultant shapes. Most of these activities would be popular with teachers since they were interesting for pupils to undertake and clearly had a place in a mathematics curriculum.

'Conspectus of Ideas' set out a summary of the geometrical ideas which would be covered from the earliest years at school to the final years in the junior school. It concluded with an overview, a copy of which follows, showing linkages which could be made amongst topics; however, this could hardly be said to be a coherent plan for a sequential coverage - rather a selection of ideas which could be pursued and investigated.

Fig 6.4 Linking topics in geometry



A very short subsection entitled 'Children's Activities' did no more than lead into a number of longer sections which addressed specific issues in detail. The first of these was called 'Filling three dimensional space', and a comprehensive range of suggestions was given which would give pupils experience of filling space, utilising marbles, small balls and cubes. Making 'standard' cubic inches from paper and adhesive, also to be utilised in filling space, introduced standard measurement. Putting together a wall using large wooden bricks led to a description of different kinds of bonding - English, Flemish and stretcher, for example. It also led into an initial discussion of the measurement of volume using the dimensions of length, breadth and depth.

The second section, 'From three dimensions to two' began by showing children's work on floor patterns, using rectangles and squares arranged in various ways. It was followed by further examples of pupils' work illustrating different kinds of symmetry, utilising blot patterns (reflection), paper folding (bilateral), a mapping about an axis of symmetry and symmetrical characteristics found in examining leaves. 'Modern mathematics' and its terminology was never very far from the authors' interest and an extension of the treatment of symmetry led to a discussion of rotation, translation and reflection of patterns. In this context, an example of lino prints illustrating translation, undertaken by nine year old children, follows.

Fig 6.5 Illustrating translation

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An extensive subsection of 16 pages was devoted to ideas on promoting an understanding of the concept of area and an experiment was suggested to help the teacher determine whether a child had acquired conservation of area. A subsection concentrated first on right angles and half right angles, and gave suggestions for activities with children using a knotted rope stretcher in the proportions 3:4:5.

The penultimate subsection of the book gave, for the benefit of the teacher, an academic treatment of the terms 'equivalence', 'reflexive', 'symmetric' and 'transitive'. However, the style of writing would ensure that most primary school teachers in the mid 1960s would find this section extremely difficult to understand.

An endeavour to reinforce the use of the terminology and diagrammatic representation involved in sets, intersection of sets and union of sets, was presented in the final subsection through a module entitled 'Classification of 2D shapes'. Conclusions were both stated in words and illustrated with Venn diagrams

(iii) *Graphs leading to Algebra*

Two books in this subset are sampled; the first entitled *Pictorial Representation* [42] and the second essentially carried the same title as the subset - *Graphs leading to Algebra 3*.[43]

Pictorial Representation concentrated on the making of simple graphs, sometimes using two dimensional, sometimes three dimensional materials. For the reader there was a discernible excitement in this presentation and the authors conveyed an enthusiasm for their subject which was not always apparent in other work of the Nuffield Primary Mathematics Project.The book offered a wealth of suggestions for activities for children which would have underlined the usefulness and attractiveness of various kinds of pictorial representation. Many examples of children's work in this field reinforced the message which the authors were trying to convey.

The main question which was explored in the first subsection was 'what can graphs do?'

With illustrations, the authors showed that graphs gave information in a concise form, pictured relationships, presented information which needed interpretation, provided material for computational practice and provided opportunity for discussion about the graphs themselves and about potential links with other subjects such as science or social studies.

The second subsection about the mathematics in pictorial representation was relatively short, two pages only. There was an emphasis on the use of mathematical language and on the use of modern mathematics terminology and symbolism and five subheadings were briefly explored: computation, set language, inequalities, mapping, measuring and symmetry

'Stages of Development' was 24 pages long and described five stages through which children need to progress in order to benefit thoroughly from undertaking forms of graphical/pictorial representation. Firstly, illustrating comparisons through one to one correspondence using a small number of three dimensional materials such as wooden bricks or milk bottles; at stage two (and invariably employing more data), utilising a longer lasting form of recording, such as using coloured match boxes attached appropriately to the chart to represent each child's birthday month. Stage three led to recording data using identical sized adhesive coloured squares to facilitate comparisons. Stage four charted the progression of this form of representation to the use of squared paper and the colouring of individual squares whilst stage five suggested the use of coloured strips, their length proportional to their value, as an introduction to the bar chart. The concept of the bar chart was considered to be quite sophisticated compared to the simple block diagram and a number of pages of the text were devoted to a discussion of projects where it might be utilised.

Nine pages of illustrations showing examples of children's pictorial representation of data followed. One of these examples follows. This was produced by a girl aged 10, and made history come alive. Her graph concerned a mine disaster and the representation of the frequency of ages of those who died. The data, which came from a newspaper of 1918, made clear the scale of the tragedy of this occurrence and the girl's comments about the deaths of youngsters who had just left school made for touching reading.

Fig 6.6 A pit disaster in January 1918

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In recording data in a pictorial manner it was essential that a discipline of procedure was followed; the penultimate section of this book (entitled 'care needed') dealt with the requirement to adopt conventions in labelling axes and with the need to standardise the size of blocks or symbols in order to prevent incorrect assumptions about magnitude. Vocabulary associated with pictorial representation was the subject of the final subsection, with short explanatory paragraphs about the axis of a graph, about frequency, tallying, block charts, bar and bar line charts, pie charts and isotypes.

Compared to *Pictorial Representation* the text of the third book of this subset - *Graphs leading to Algebra* 3[44] - was dense and unrelieved. There were eight subsections; the first concerned with graphs and scale drawing and the second with graphs from experimental work; even these contrasted strongly with the presentation of the later subsections, in which written algebra appeared to have the ascendancy over graphical representation. Subsection two was concerned with an important concept - that of elementary extrapolation; for example, following the plotting on a graph of the relationship between the length of an elastic band and a number of gram weights hung from it, can an estimate be made from the graph about the length of the elastic band if an additional weights were added?

Subsections three, four and five addressed a range of topics; for example open sentences, multiplication of integers and signed rational numbers. These were presented in a somewhat turgid manner; this was surprising, given the avowed aim of the Nuffield Primary Mathematics Project to convey ideas to teachers in an interesting manner in order that they could, in turn, make it easier for children to learn.

Subsection six, focusing on graphs using signed rational numbers, was for the most part concerned with plotting straight line graphs of the type $y = 2x$ or $y = 2x + 3$ and with discussing a number of issues such as the slope of the resultant lines and their intersections with the x and y axes. Subsection seven addressed mathematical inequalities and intersections and began to develop a graphical approach to the solution of problems such as $y > 2x$, $y > x^2$, and $xy > 12$.

The last subsection, of 16 pages and entitled 'The Algebraic Solution of Equations' was distinguished by having no illustration of any graphical representation at all. It focused on the reflexive, symmetric and transitive properties of an expression. Because of the complexity of the explanations, it seemed difficult to justify the inclusion of this topic for non-specialist teachers working in a primary school.

The book concluded with an appendix on rational and irrational numbers in the form of a note for the teacher, which once again seemed difficult to understand without a comprehensive mathematical background. In fact, this book, and the manner in which it was written, might have done a great deal to negate incipient interest in mathematics for teachers.

Weaving guides

Probability and Statistics (1969) [45] will be examined in detail as an exemplar of this series. This guide demonstrated the many ways in which data can be collected and organised but in particular it stressed the need to build up a critical approach to the presentation of statistical data and to methods of predicting probable outcomes.

The first section of this book of 50 pages discussed the introduction to young children of statistical ideas; it considered the reliability of a common statement such as ' "Floorsmear" makes your floor twice as shiny as any other polish'. Children were encouraged to consider the verifiability of such statements and indeed to consider which statements were verifiable.

The next section was entitled 'Early Uses of Pictorial Representation'; the content was similar to that in *Pictorial Representation*. Various ways of collecting information were discussed: census, count or measurement, questionnaire and random sample. Important questions were raised, for example, 'Are the members of the school orchestra a random sample of pupils of the school?' A subsection on recording and tabulating data followed, suggesting the usefulness of a 'tally' in some circumstances, as in determining letter frequency in text. An illustration of a child's work in this field, taken from the book, follows. It was clear that ‘e’ is the most popular letter, closely followed by ‘a’ and ‘t’. This would be a useful exercise for pupils if the conclusions were incorporated in future activities in English language work and prose composition.

Fig 6.7 Letter frequency in text

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'Illustrating statistical data' discussed the appropriateness of both line graphs and block charts in representing data, comparing, for example, the change in temperature in a classroom during the working day (dotted line joining recorded points) with block diagrams representing unemployment figures; particular note was made, in the latter case, on the perception of magnitude by a viewer, (in this case of the extent of unemployment) of the effect of setting, or not setting, the base line x axis at zero, i.e. at y = 0.

The next section of 18 pages looked at games, leading to ideas on probability. A range of activities was discussed: predicting the number of heads/tails which appeared in tossing one coin 100 times, then in tossing two, three or more coins a similar number of times. However, by far the longest subsection was devoted to a consideration of throwing dice, where the student was asked to predict and then tally the frequency of scores one to six in tossing one dice 100 times and similarly in tossing two or three dice 100 times. An example of a child's work in this field follows. Wendy, aged seven, had thrown two dice 181 times and registered the total score in each case, plotting the results. It is clear to her that the highest frequency of scores rests with totals of 7 and 8. Apart from the practice of simple addition, Wendy was gaining an understanding of basic probability; she made the discovery that it is impossible to score just 'one' and justifies her explanation.

Fig 6.8 Throwing dice: illustrating probability

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Discussion about sampling centred on the circumstances in which it was appropriate to take a sample of a population and on how this could be done in order that the information obtained would be reliable. The concept of random sampling was discussed as was the relationship between the degree of reliability and the size of the sample. Recording of data in a grouped frequency distribution and its expression in the form of a histogram was illustrated, followed by a survey of the different ways of determining an average - the mode, the median and the mean. Examples of where each of these measures of average was most appropriately used were given; it was likely that this treatment would have been one of the earliest endeavours to bring all three to the attention of teachers in schools and the children for whom they were responsible.

The last subsection of the book was entitled 'measuring probability' and tried to impart some degree of understanding to this complex topic. The 'expectation' of an event was discussed and related to the number of occasions in which an experiment must be carried out in order to give some statistical credence to statements of probability of occurrence. The predicted probability of a coin showing a head when tossed is 1:2 but it is unlikely that this could be substantiated until the coin had been tossed many times. Compound events, such as the probability of two heads, two tails, one head/one tail appearing when two coins were tossed or the possible scores when two six-sided dice were thrown were also explored.

Essentially this 'Weaving guide' did exactly what the general introduction to the literature indicated; it gave helpful information about a particular subject and illustrated how the topic might be taught; by this definition *Probability and Statistics* was successful.

Check-ups

In the Project literature, much was made of the difference between a child's ability merely to carry out a series of drills or 'sums' - where success could be measured as a consequence of remembering techniques alone - and a real understanding of the underlying mathematical concepts. The general introduction in *Checking Up 1*,[46] the first of the

'Check-ups' series, noted that 'the traditional tests are difficult to administer in the new atmosphere of individual discovery and so our intention has been to replace these by individual check-ups for individual children'. The Project had made contact with Professor Jean Piaget in Geneva and this resulted in the development of a series of guides for teachers, based on Piaget's work, but linked to the Project's Teachers' guides. *Checking Up 1*, written by Professor L Pauli and Miss Joan Bliss, under the supervision of Professor Piaget, was published in 1970 and focused on number; it will now be reviewed briefly as an exemplar of this set of guides.

Acknowledging Piaget's conclusions about the acquisition of concepts by children, the guide noted that it was generally thought that these cannot be *taught* to children, rather that children gained levels of conceptual understanding as they passed through a series of cognitive stages. It was suggested, however, that this understanding could be enhanced and even quickened by exposure to activities in the classroom and elsewhere as children handled appropriate materials. The 'Check-ups' were said not to be intelligence tests; they were more in the nature of milestones that would chart a child's intellectual development for the teacher, in this case in respect of mathematical concept formation.

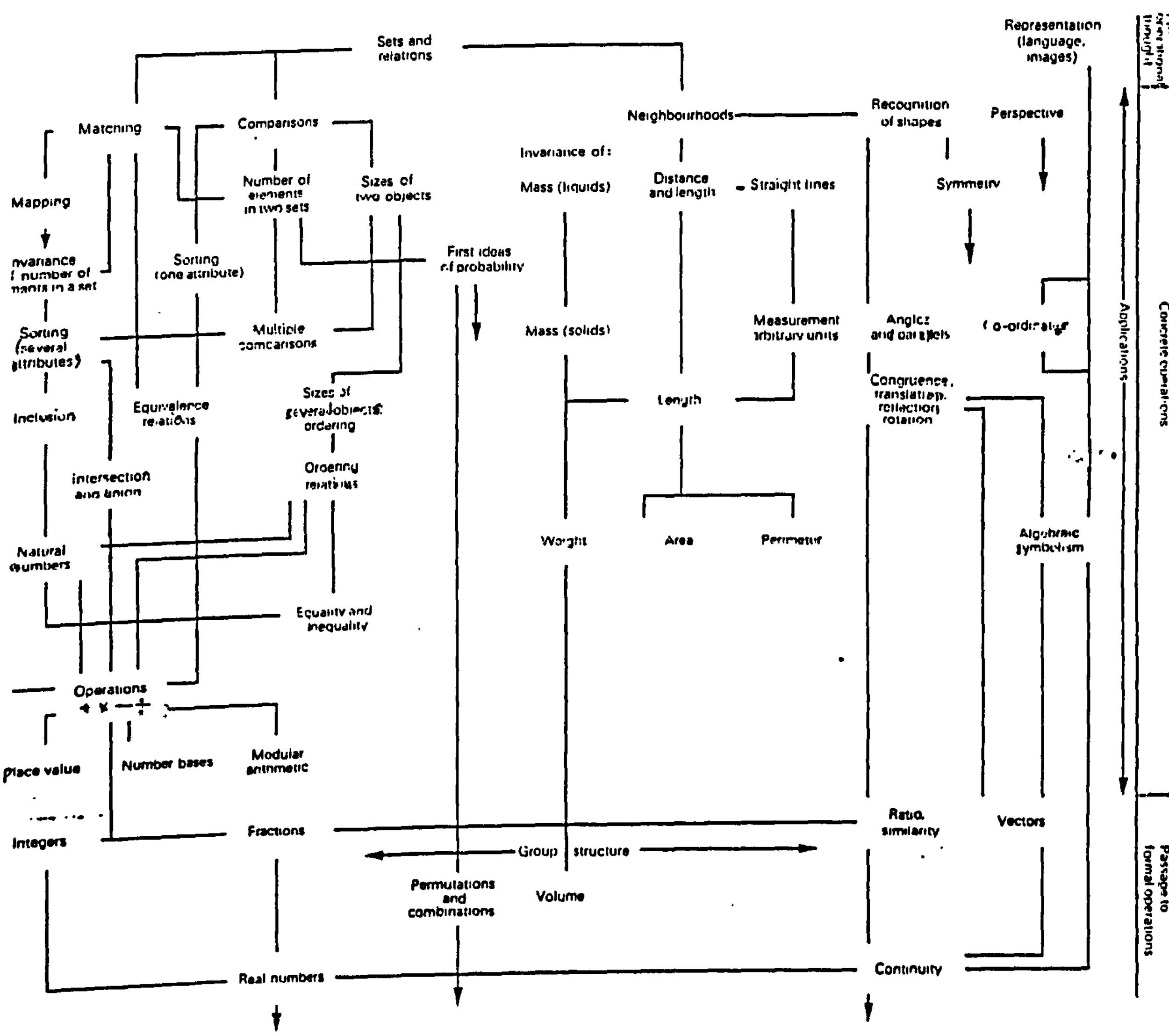
The first section of the book concentrated on one-to-one correspondence - on the fact that, for example, five items were identical to any other five items in terms of number no matter what configuration was adopted in the groupings; suggestions were given for activities which might assist children in acquiring the concept of invariance of number.

Section two of the book dealt with 'relations', drawing attention to suggestions which were made in *Mathematics Begins*,[47] in order to give children experience of vocabulary such as 'taller than' 'longer than'; it then moved to 'ordering', or ordinal measure, in a variety of situations. The authors used, in section three, the notion of the set as a vehicle to illustrate relationships through sorting, classifying and comparing activities, whilst sections four, five and six concentrated on relationships which were manifested under the headings of inclusion, union and intersection of sets.

The appendix set out five summary 'Check-ups' which related to the topics which have been discussed in the guide. The first 'Check-up' focused on a child's ability to understand one to one correspondence; it listed the materials which were required (bricks and counters in this case) and the questions which the teacher would put to the child. It also detailed some of the responses which the child might give and indicated supplementary questions and activities which it would be appropriate to use in investigating a child's understanding of this concept. The other four 'checkups' successively investigated the understanding of multiple comparisons, ordering, sorting and inclusion, and intersections.

No children's work was shown in this guide; a diagram, which follows, showed some of the concepts which children needed to acquire over years and linked them tentatively to Piaget's stages of pre-operational thought, concrete operations and formal operations.

Fig 6.9 Concepts which pupils need to acquire



The Check-ups represented an attempt to assess a child's understanding of a mathematical statement or process. They were extensive and detailed and for that reason an educator of the 1960s and 1970s suggested that their use was impractical for busy teachers. The Nuffield team itself was said to be divided on the issue.[48] However, two other educators reported that the Inner London Education Authority (ILEA) 'Checkpoints', [49] published in the mid 1970s, exceptionally well regarded and extensively used in schools, developed many of the ideas from the 'Check-up' materials.

<u>Other Publications</u>

A number of additional publications were commissioned by the Nuffield Primary Mathematics Project between 1967 and 1973. As a sample, a slim 18 page volume, principally written for teachers undertaking in-service training, entitled *Maths with Everything,* [50] and published in 1971, is reviewed and one example of the three part set of *Problems,* designed for young secondary school pupils.

Maths with Everything had the same title as a film produced by the Project at about the same time; both were concerned with the mathematical experiences of infant children, aged from five to seven years. In the first part, the book described various approaches to mathematics teaching to which young children could be exposed and stressed the importance of finding mathematical experiences in school and home activities, whilst the second part addressed elements of in-service training for teachers.

The authors reviewed four of the approaches to teaching for younger children. First was the 'archaic', traditional and didactic, where pupils worked mainly from the textbook concentrating on gaining a facility with number and tables facts, invariably through repetition, chanting and practice. The second was 'learning by doing' where the practice of sums in the first session of the school day was replaced by an activity period in which materials and apparatus, either professionally made or home produced, were introduced by the teacher. For example, the professionally made Cuisenaire Rods - structured apparatus which could lead to a variety of discoveries by a child about number relationships - and the provision by the teacher of cleansed yoghurt pots in the mathematics corner of the classroom facilitating practical activities related to capacity. A third approach introduced mathematics into as many other activities of the school day as possible, for example, through the teacher drawing children's attention to the one-to-one correspondence between the paint brushes and the paint pots during a craft session. The final theme ensured 'maths with everything', whereby, with the teacher's help, most creative activities in school were seen to have a mathematical component.

The text in the first part of this book reflects the sheer enthusiasm of the authors for their proposals and the thrust of their message was illustrated through a variety of methodological ideas for teaching and learning. *Maths with Everything* encouraged teachers, and indirectly the pupils, to enjoy and to understand mathematics; what it did not do, however, was suggest any logical progression, or to justify or to evaluate its approach.

The second part of the book commented on the film *Maths with Everything*. Activities in class at the ILEA Thorntrees Infants School, Charlton, London, focused on the topics of length and weight and on the mathematics involved in a 'bus' project. The text also elaborated on the commentary accompanying a section of the film about an in-service training session for infant school teachers involved in the bus project, once again stressing how mathematics formed an essential feature of its development.

Eight pages of the book were given over to visual extracts of the film scenes, principally concentrating on playground and classroom activities, but with some acknowledgement of in-service training activities for teachers. An example of one of the eight pages of photographs follows. Children are seen undertaking practical work in class and teachers preparing materials during an in-service training day.

Fig 6.10 Practical work in class and teachers preparing materials

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The collection of *Green Problems*[51] - one of three, the others being labelled *Red and Purple* - was published in 1969. The complete set represented the main contribution of the Project to activities for the lower secondary age range and were the nearest the Project came to producing exercises for pupils.The problems were also published as collections of separate cards. They were extremely popular and 'sold like hot cakes'.[52]

The problems in the Green set covered a range of mathematical subject matter. Four examples of the 52 problems are reviewed. The first looked at the various ways in which squares and square numbers can be built up practically, but then elaborated the exercise by counting the total number of squares which can be found in the drawing. For example a one by one square contains only one square but a two by two square five squares, four small squares and one large square; a three by three square contains nine small squares, four two by two squares and one three by three square, a total of 14 squares. Of itself this problem is not particularly significant, but it develops basic information about the build up of squares in a manner which takes the original investigation much further.

Problem 12 focused on the number of handshakes which will occur at first meeting between two, three, four....... people. The operation is represented geometrically in a series of diagrams of increasing complexity, but as in the first problem, the solution is generated as a practical exercise and the results tabulated. A pattern for the number of handshakes for an increasing group size develops and this is seen to be the same as for the development of triangular numbers. The theme is then developed to elicit a generalisation in the form of an algebraic statement which, in a readily understood argument is shown to be n(n - 1) divided by 2, where n represents the number of people who meet each other.

Problem 44 is interesting in that it addresses a question which, to achieve an answer, would appear to require an effort of herculean proportions - how many grains of rice are there in a pound weight? Sensibly an answer to this question can only be a close approximation, but the procedure which involved the counting of rice grains in one ounce and then multiplying by two and repeating multiplication by two until an estimate for the number of grains in 16 ounces was obtained, gave a tolerably accurate answer. The significance of this problem lies in the fact that it gave students an insight into a means of answering a question which at first sight appears virtually impossible. The methodology learnt could then be applied in similar circumstances.

Problem 52 targets the possible arrangements for fitting a red and a yellow pane of glass into a three section framework. Trial and error showed that panes of such glass could be arranged in eight ways. The scope of the problem was enhanced by utilising the binary system, defining the red pane as '1' and the yellow pane as '0' and expressing the possible arrangements in tabulated form in base two, that is 111 through 000. Once again the basic idea in the first part of the problem has been elaborated to generate investigations in a different sphere of interest.

The authors of this set of problems appeared anxious that pupils should have a thorough acquaintanceship with the binary system. Each problem, from 1 to 52, was captioned both in the denary and binary systems, the latter in large type, so that for example, and respectively, 10 was given as '001010' and 50 as '110010'.

Overall the problems covered a range of interesting topics which would be attractive to many young secondary stage pupils. The authors can be commended for extending the basic investigation of a topic to show how other facets of mathematical study could be generated from a simple beginning.

<u>The Appearance and Presentation of the Teachers' guides and other publications</u>

Most of the Project books were produced in a landscape format with dimensions 22 cm by 20 cm, almost square. The cover designs, rather like those emanating from other schemes, such as the Schools Mathematics Project and the Maths for the Majority Project, were colourful and eye catching, attracting immediate attention, not least because they were vastly different from much that had been produced in the mathematics field before. The text was arranged on each page in two columns, with short paragraphs and adequate spacing between lines, enabling the reader to assimilate the arguments which the authors were conveying easily.The content alternated between words, diagrams, sketches, charts and pictures and the varied format, on the whole, maintained interest.

Although one of the Project's aims was to make mathematics more understandable and accessible for both primary school teachers and children, the quality of the presentation of the Teachers'guides did not always facilitate that aim.The first, *I do and I understand*[53] and a later production *Pictorial Representation*[54] were exciting and persuasive, but others, especially in the main series *Shape and Size* and *Computation and Structure* ran the risk of being unnecessarily repetitive in approach and static in content. *Graphs leading to Algebra 3*[55] required a substantial amount of mathematical expertise to understand and would not be helpful to primary school teachers of the day, many of whom did not possess a basic GCE 'O' level qualification in the subject. Some sections of guides, usually those focusing on complex mathematical topics, led to turgid and tiresome reading.

The impact of the Project

The 1960s reflected a time when the progressive movement was at its most prominent, when changes in the methodology of teaching were being strongly canvassed, when Piaget's conclusions were seen to have major implications for classroom practice, when crucial evidence which found its place in the *Plowden Report*[56] was being thought through and when new mathematics content was being introduced in schools.The Nuffield Primary Mathematics Project enjoyed maximum opportunity to flourish and for its suggestions to be accepted by teachers and by other educationalists. What then was the nature and extent of its impact?

The ideas which the Nuffield Project conveyed were very popular with teachers and by 1968 2000 primary schools in 130 areas, each having access to at least one teachers' centre, had joined the Project.[57] It was credited with the large scale establishment of teachers' centres across the country, since being a member of the Project required LEAs to make such provision. Many well attended and practically oriented in-service training courses focusing on the materials in the Teachers' guides took place in the years between 1964 and 1972. Geoffrey Matthews commented that the Project 'opened teachers' eyes to mathematics'.[58] The attractive and colourful appearance of the guides made them immediately recognisable and served to reinforce the concept of 'Nuffield mathematics'. Nearly one million copies of the 20 guides[59] produced during the lifetime of the Project were sold, with those focusing on work with young children being the most popular.[60] Sales of the guides were so successful that after receiving an initial setting up grant from the Foundation, the Nuffield Primary Mathematics Project was self-funding throughout the rest of its life and did not then require, or seek, financial assistance from the Schools Council or any other body.[61] The success of the operation was such that it became possible to return £87,500 to the Nuffield Foundation, a rare event and perhaps a measure of the Project's effectiveness.[62]

There was evidence that the Project did have an effect on the way in which mathematics was taught and learned in the late 1960s and 1970s. In 1967 HMI were quoted, in evidence to the Plowden Committee,[63] as indicating that a majority of schools had been influenced by the developments of the last five years and a substantial minority, something between 10% and 20%, had completely rethought and reorganised their mathematics syllabus and teaching methods.

The impact of the Project was enhanced by the production of three films illustrating the work of the Project: *I do and I understand* - at junior school level; *Into Secondary School* - at lower secondary school level; and *Maths with Everything* - about infant school activities. All were shown regularly at teachers' courses, and focused principally on changes in methodologies of teaching and learning. The Project's ideas were taken up in five television programmes produced by the BBC in 1966-67, aimed at parents and teachers, entitled *Children and Mathematics*, which gave the work of the Project wider publicity.[64] Following the making of the film *I do and I understand* by the Nuffield Project and the publication in 1965 of the Schools Council's *Curriculum Bulletin No.1: Mathematics in Primary Schools*, the BBC gave practical support for new approaches to teaching mathematics in primary schools through the production, in 1965-66 and again in 1966-67, of a series of 20 weekly stimulus television programmes over two terms aimed at pupils between nine and eleven years of age, entitled *Primary School Mathematics.*[65] The series included - unusual because of the costs involved - film of pupils engaged in mathematically relevant activities.[66]

A magazine, the *Bulletin* of the Nuffield Mathematics Teaching Project, which contained teacher comment and suggestions for classroom approaches, was circulated to schools via LEAs. The *Bulletin* was the responsibility of Don Mansfield - one of the early contributors to the School Mathematics Project, through its utilisation of *Mathematics: A new approach: Book 1*[67] - which Mansfield co-authored with D Thompson - in the four grammar schools involved in the initial stages of that Project's implementation. Geoffrey Matthews was said to have considered the *Bulletin* an unmitigated failure,[68] largely because of a mismatch between the expectations of the Director and Mansfield's interpretation of the required focus for the content, which proved to be too academic for the targeted audience.[69] It continued independently as *Mathematical Forum*[70] after the conclusion of the Project in 1972.

The Project was recognised not only nationally, but internationally as well. Two volumes, entitled *Mathematics: the first 3 years*[71] and *Mathematics: the later Primary years*[72] which constituted an amalgam of some of the original Nuffield Teachers' guides, were jointly published in 1970 and 1972 respectively by the Project and the Centre for Educational Development Overseas (CEDO), which drew most of its funds from the Ministry of Overseas Development. They were mainly distributed within the New Commonwealth countries, to assist in the task of curriculum regeneration at primary school level which had by 1970 become a matter of serious debate. Geoffrey Matthews visited widely overseas to publicise the philosophy and practice of the Project, including in Brazil, India, Nigeria, and Sri Lanka.

The author, during his secondment in 1971 and 1972 by the British Council to the Federal Inspectorate of Schools in Malaysia on a short term contract as a primary mathematics specialist, composed an integrated mathematics syllabus for use in schools, where topics under ten headings, for example quantity, length, area, balance, time and visual representation were linked together, reflecting the approach to many of the concepts which informed the Nuffield Primary Mathematics Project. A copy of the document can be found inside the back cover of this thesis.[73]

Early in the life of the Project, Geoffrey Matthews had made clear that it was not going to produce a 'package deal' for teachers in the form of textbooks and schemes of work - a decision which was the cause of considerable tension within the team, and which in turn created dissemination problems for the Project which it did not have the resources to overcome.[74] Matthews defended this stance by arguing that his strategy was 'to produce simple guides for teachers ... who would develop their own curriculum'.[75] Such a task proved difficult to carry through, bearing in mind the revolutionary nature of much that was suggested. More generally, the problem of dissemination of new ideas was exacerbated by the lack of mathematical background of most teachers in primary schools, by the high proportion of underqualified teachers in some schools, especially in inner city areas, by large size classes of 45 pupils and above, and by the frequent changes in staffing establishments.[76]

In 1975, Hewton wrote 'Many teachers, who would have otherwise firmly supported the approach, have been disappointed by the absence of Project-produced pupils' materials for most age groups'[77] whilst Howson, Keitel and Kilpatrick[78] saw their absence as limiting the effectiveness of both the Nuffield and Mathematics for the Majority Projects. The teacher would be more likely to rely on a textbook series, for example *Oxford Junior Mathematics*,[79] traditional in content but modern in approach, or Flavell and Wakelam's very popular *Primary Mathematics: an Introduction to the Language of Number*,[80] to provide a coherent programme.

The Teachers' guides included many suggestions for activities, but it would be difficult for a teacher to find time in a busy professional life comprehensively to follow up the proposals in the guides, or to react sensitively to the educational philosophy of the Project. It would have helped teachers to have had access to an infrastructure in which the new content, or even the new methodologies of teaching, could be embedded.The team of writers, experienced educationalist practitioners, guided by a mathematician Director and immersed in their work on a daily basis, could no doubt see a progression in the recommendations they made. Such understanding may not have been vouchsafed to a busy teacher in a primary school. It was more likely that any major discussion of educational ideals, of the 'discovery' approach, of the implications of Piaget's research conclusions about the need for children to handle materials, of the work of new curriculum projects and the materials they produced, took place in universities and teacher training institutions, rather than in classrooms. Indeed, personal observation indicated that Teachers' guides and other materials produced by projects, including those from the Nuffield Primary Mathematics Project, were in abundant supply in colleges of education and were actively discussed by staff and students alike. In contrast, a recent communication from a researcher of the time reported that the supply of guides in schools was never large and could be minimal or non-existent, depending on the priorities of the headteacher, who controlled financial outlay.[81]

Geoffrey Matthews, in recent extensive discussions with the author, indicated that he still felt it was right for the Project to have relied upon the Teachers' guides, and the suggestions and explanations they contained, to generate modifications in primary school mathematics, rather than upon the production of pupils' materials. It is clear, however, that for a number of reasons, his confidence in teachers to implement change was not matched either by their ability, or by their wish, to respond in any complete sense.

The absence of pupils' materials, with the exception of the production, late in the life of the Project, of a small number of module packs containing work cards for the use of older students, had an indirect consequence, in that publishers, responding to the climate for change which Edith Biggs and the Nuffield Project had generated, produced - as Professor Wrigley, who directed the Primary School Evaluation Studies Project at Reading University for the School Council in 1972, wrote - 'a great rash of courses, ... the most widespread series...being generally known as *Fletcher Mathematics*'.[82] Its full title was *Mathematics for Schools.*[83] The series was strongly commended by three of the educators active in the 1960s and 1970s.

There is, however, some negative evidence to be taken into account. Much space in the guides was devoted to a consideration of modern mathematics topics such as 'sets' and 'subsets', to mappings, to the drawing of Venn diagrams.

Thus, by way of example:

traditional	*modern*
	Command : add ordered pairs of numbers
$6 + 0 = 6$	6,0 → 6
$5 + 1 = 6$	5,1 → 6
etc	4,2 → 6
	etc

In themselves these suggested changes were not particularly difficult to comprehend and indeed resulted in the production of much attractive children's work. However, doubts about the messages which the Project was giving were raised in the minds of teachers in primary schools, the vast majority of whom were non-specialists and did not understand the justification for changing from one system of expression and its symbolism, which was seen to be perfectly adequate, to another which fundamentally did not seem to give any significant advantage over the former. In practice, the introduction of these new topics led to some difficulties for primary school teachers since the majority were totally unfamiliar with these new approaches.

Given the strong thrust towards the introduction of 'modern mathematics' materials at the secondary education stage in the mid 1960s, reflected, for example, in the output of the *School Mathematics Project,*[84] and, given the previous experience in this context of the Director of the Project, for example in his editorship of and contribution to the *Contemporary School Mathematics*[85] booklets, it is understandable that topics in modern mathematics should extensively permeate the Nuffield Project. Indeed such approaches accorded well with its declared aim - to devise a contemporary approach to mathematics for children from five to 13. Although Geoffrey Matthews lacked primary school teaching experience, it is clear that, taken together, his status as a mathematician and his experience as a dynamic teacher far outweighed this deficit. He was, in any case, strongly supported throughout the Project's life by an able practitioner, infant school headteacher Julia Coomber, (later Matthews).

There were a number of individuals, principally working in colleges of education at the time, who might have been considered for the role of Project Director, and who undoubtedly would have been supportive of change in mathematics curriculum content and in the methodology of teaching in primary schools. But they were neither academically Matthews' equal, nor could they match his connections at the highest and most influential levels of the educational establishment.

Geoffrey Matthews confirmed this conclusion in 'Demon King Replies',[86] in response to Ian Thompson's article '"Prenumber activities" and the Early Years Curriculum'[87] in which the latter expressed some surprise at Matthews' appointment as Director of the Project, principally on the grounds of his lack of primary school experience. Matthews wrote 'I had my arm twisted by HMI who told me they had spent a morning discussing who should be recommended for the job and my name was the only one which had emerged'.

Perhaps, however, under the influence of this Project, the balance of the curriculum menu had gravitated too far towards the pure discipline of the subject, often expressed by an emphasis on the symbolism and practice of 'modern mathematics' and away from the need for children to acquire traditional basic skills and experience in the ways in which mathematics was used in everyday life. Ian Thompson argued that some of the ideas put forward in the guides, whilst mathematically sound, may not have been educationally sound in enhancing a child's incremental progression towards understanding.[88] He went further in arguing that Matthews' interest in mathematical precision and rigour was apparent in the Project's approach to number and asked whether a study of sets, mappings and relations was a necessary prerequisite to an understanding of number.[89] Moon[90] noted that the requirement to use the very precise terminology associated with practice in 'modern mathematics' led to ongoing conflict between Geoffrey Matthews and Edith Biggs (and, within the author's knowledge, some members of the team), during the life of the Project.

It is significant that Professor Wrigley's evaluation study [91] reported that 29% of primary school teachers invited to respond to questions about the reservations they had about the way in which primary mathematics was taught today (1972) indicated concern at the neglect of basic processes; many teachers expressed worry that some children were not getting enough practice and revision in the fundamental skills of computation. In 1973, Gardner et al observed that even where integrated work in schools was functioning smoothly and successfully, time should be set aside for specific work in mathematics, with the objective of practising skills which had emerged.[92] These comments appear to question the priorities which the Project set at its inception.

Nevertheless, with some reservations, the Project's suggestions for a change in the methodology of teaching mathematics were, on the whole, sympathetically received by many teachers at this time. It is clear, however, that they still wanted to give their pupils an adequate exposure to basic skills and the associated practice exercises.

It was forces external to teaching which began to challenge the Project's philosophy and practice - and indeed its apparent success. The second 'Black Paper' in 1969, and particularly the wide ranging article by G H Bantock, entitled 'Discovery Methods',[93] deplored the lack of a structure or a learning plan in promoting discovery work. He suggested that the informal approach of working with whatever materialised, especially in investigating the environment, resulted in a 'magpie curriculum'.

There was no formal evaluation of the Project overall. In 1965, the Schools Council, anxious to determine whether the work of the Nuffield Primary Mathematics Project would result in a demonstrable improvement in mathematics teaching and learning, funded a three year research project at Reading University, estimated by the Council to cost

£5750.[94] The study was under the direction of HMI T M Murray Rust, who was attached to the Project to carry out the task. Its terms of reference were to study and evaluate the development of Nuffield Primary Mathematics Project activities in the first and second phase areas.The study, however, was abandoned prematurely, owing to differences of opinion between the Project Director and the Research Study Director in respect of the Project itself.[95] Informal evaluation of Project activities was effected through feedback received from teachers during regular visits to schools and teachers' centres by the writing team members.The Project advocated the use by teachers of the tests in the 'Check Up' booklets to evaluate pupils' conceptual understanding. In 1975, Hewton gave a positive appraisal of the Project in his extensive profile of the scheme, in which he concluded that 'the ideas which it generated in relation to both content and the approach to teaching primary school mathematics have been diffused widely and have reached a high proportion of teachers, with sales figures suggesting that over 50% of primary teachers at some time acquired Nuffield Mathematics materials'.[96]

One educator of the time maintained that the Nuffield Project had a dominant influence on change in primary school mathematics, whilst in 1976, F R Watson wrote:

> When it finally drew to a close in 1971 (1972) the Project could fairly claim to have made a major contribution to developing and extending the changes in primary mathematics education which had preceded it. Large numbers of primary teachers had attended courses on mathematics teaching and in many schools the suggestions of the guides were being taken up.[97]

In 1999, Ian Thompson, in the DfEE's *Book Two* of the *National Numeracy Strategy Professional Development* document, argued:

> It would be difficult, 26 years later, to find a commercial mathematics scheme aimed at children in their first years of schooling which does not treat early number in a similar, if not quite so rigorous manner. All such schemes surveyed recently by the author clearly illustrate the extent to which they have been

> influenced by the early Nuffield Project, although this influence may well have been via indirect sources - Teachers' Centres, LEA or University courses, books on mathematics education, maths schemes - which in turn were most likely to have been influenced by the Project.[98]

Overall, evidence suggests that the impact of the Nuffield Primary Mathematics Project was considerable; it changed the way mathematics was taught in most primary schools and enlarged the content of the curriculum. It contributed to changes in the appearance and presentation of textbooks and other resource materials which are reflected in many of the pupils' books which are currently in use. However, the concentration in the Nuffield Guides on 'modern mathematics' topics such as sets, its associated terminology and symbolism, Venn diagrams and motion geometry has assumed a far less dominant place in the content of books used today, for example, *Ginn Mathematics, level 6, Book 1*,[99] *Mastermaths 4*,[100] by P Briten and *Numbers*,[101] by K Bryant-Hole. Much of the traditional has reasserted its pre -1960s status with the inclusion of topics such as factors, prime numbers, fractions, decimals, percentages, ordering, grouping, multiples, ratio, congruence, triangles and averages. On the other hand, there are a significant number of topics which were first extensively seen in the Nuffield guides - elementary statistics and the representation of data, minus numbers, directed numbers, estimation, probability, flow charts, coordinates, symmetry and tessellations.

The Project was in the vanguard of development with its propagation of exciting new, almost revolutionary ideas, especially in relation to 'modern mathematics' content and its support for changes in teaching methods through the advocacy of child-centred education, discovery work, group activities and investigations of the environment. Although the sharp thrust of suggested changes in the teaching of mathematics initiated by the Nuffield Primary Mathematics Project is now muted, reflecting the restrictive influence of the National Curriculum and the Government guidelines on the teaching process, a discernible legacy of the Project still remains in the content of many of the books available to pupils and teachers in primary schools.

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Chapter seven

CONCLUSION

The 1960s and early 1970s represented a period of liberalisation of society, coupled with a widespread expectation of improvement in the quantity and quality of educational provision. There was an excitement and optimism in the attitude of professionals in this field, which was reflected in their willingness to engage in an enthusiastic consideration of new curricula and skills, and of new methodologies for their delivery to pupils.

This enthusiasm was manifested through intense discussion of alternative programmes of study for use in primary and secondary schools, and, more specifically, in the establishment of numerous curriculum development projects, some under the aegis of the Schools Council, others independent of that body. These initiatives were largely driven at the secondary school level by the prospect of the raising of the school leaving age and the implementation of comprehensive education. At the primary school level, in the mid to late 1960s, serious consideration of change in approaches to teaching and learning, and, to a lesser extent, to new content, grew out of the ending of the 11+ examination and the application of more informal and child-centred methodologies, reflecting the strong influence of the progressive movement.

This thesis has filled a gap in the literature in assessing the overall impact of three major mathematics projects of the 1960s and in appraising their success or failure. It has looked at teachers' attitudes both to new mathematics curriculum content and to revised teaching methodologies. It has examined the principal forces responsible for curriculum change in this decade and assessed their effectiveness. It has considered whether teachers' professional status was enhanced by their involvement in projects and initiatives, and in delivering in-service training. It has posed the question as to whether pupils benefited by spending time in discovery or investigatory activities and whether such time would have been more constructively employed in acquiring basic skills in the subject.

The following conclusions can now be drawn.

In retrospect, certain features about this period are clear. The project activities and other initiatives generated by a number of talented individuals and by the Schools Council sensitized many teachers to the need for, and the desirability of, curricular and pedagogical change. The impact throughout England and Wales was considerable, rather more in respect of a change in the methodology of teaching in the primary sector and rather more in respect of content in the secondary sector. Nevertheless, despite the widespread application of ideas emanating from projects and other initiatives, not all teachers were influenced in their practice by the proposed changes of the 1960s, and on balance, continuity of content and pedagogy maintained an ascendancy over change during this period.

The 1950s, 1960s and early 1970s represented a particular moment in historical time when control of curriculum rested firmly with teachers, which contrasted sharply with periods of government direction in this context both before and increasingly after this era. Teachers, supported by their unions, not only enjoyed the freedom to accept or reject ideas for a revised curriculum and the means of its delivery, but equally important, the freedom to be unwilling to contemplate change. Teachers might be persuaded to join a curriculum initiative, particularly if professional kudos attended such involvement, but there were no sanctions against a teacher who refused to participate. The application of this freedom inevitably diffused the potential for success of any enterprise. The curriculum in English schools is now prescribed and the Government's numeracy strategy for primary schools ensures that all teachers must exercise tight control over their pupils' learning. A lesson to be learnt from the events of the 1960s and 1970s is that serious curriculum reform or change requires both acquiescence and active cooperation by teachers.

The introduction at this time of 'modern mathematics' was of considerable importance. It raised a number of complex and inter-related issues. There was much confusion about the definition of the term itself. Often used pejoratively in reaction to the introduction of new content and sometimes inappropriately in reaction to new methodologies of teaching, 'modern mathematics' embraced a number of new topics, many of which were perceived by teachers to be interesting and even exciting, both for themselves and their students. However, sets, their symbolism, manipulation and representation, Venn diagrams and mappings, defined in this thesis as a subset of 'modern mathematics' topics, were not understood by many teachers. Their presence created emotive and occasionally strongly antagonistic views, since their application, especially in arithmetic at the primary stage, undermined, and was perceived to replace, traditional and well understood procedures, a point strongly made in evidence at interview by a number of educators working in this field in the 1960s, who felt the change unnecessary. These particular elements of the new mathematics curriculum, reflecting some of the ideas which were discussed at the Royaumont conference and in the UNESCO publications of the 1960s, enjoyed a relatively short life and assumed a much less prominent role in syllabuses by the 1980s.

Individual and sometimes diametrically opposed perspectives in relation to modern mathematics were linked to a number of factors, such as age, personal education and training, teaching experience, the understanding of underlying concepts, the level of teachers' mathematical competency, and views on the ultimate purposes of education. Many older teachers disliked new topics, such as sets, rotation, reflection and translation, symmetry, topology, number bases other than ten, and statistics, since their ignorance of the mathematical concepts involved inevitably posed a threat to their status and seniority. In contrast, the increasing popularity of the new materials was linked to the arrival in secondary modern and comprehensive schools of a new breed of teachers anxious to promote their careers in an examination orientated environment. As a mathematics teacher, the author was himself an early supporter of this development, although it was clear that the intellectual challenge for the pupils was huge. In the later 1960s, teachers saw the discipline of the new content, more particularly that emanating from the School Mathematics Project, with its stress on practical outcomes of classroom experience, as a means of enhancing their status.

The Nuffield Primary Mathematics Project, the School Mathematics Project, the Mathematics for the Majority Project, the Midlands Mathematics Experiment and the

Contemporary School Mathematics Project all introduced a range of topics in modern mathematics. The materials which were produced by the first two and the last of these projects strongly influenced curriculum renewal in mathematics in the ten years from 1965 to 1975 and have continued to do so until the present time.

The text and resource books available for pupils' and teachers' use in the period under review were of two types: those which fundamentally reflected traditional teaching needs and those which were published by the newly established major projects. On the whole, the mathematics text and resource books in use in primary and secondary schools in the mid to late 1960s ensured that pupils were exposed to a powerful diet of traditional mathematics content, presented by teachers in a traditional, sequential, manner. There were some changes however. Research for this thesis confirms that a substantial number of books for the primary stage, which were aesthetically attractive, colourful, with well spaced paragraphs and exercises, were published at this time. A few, such as Flavell and Wakelam's *Primary Mathematics - An Introduction to the Language of Number*, while principally concentrating on traditional content, introduced some inferential work for pupils and a small amount of modern mathematics content within an overall presentation which could be described as user-friendly.

The materials produced by the Nuffield Primary Mathematics Project from 1967 represented a significant landmark through the provision of both modern mathematics curriculum content and the advocacy of a new methodology of teaching. They are firmly based in the quadrant described in the survey of the books as 'enhanced content/ enhanced approach'. At the secondary school stage, while texts with traditional content and presentation were still extensively available, from the survey of books available in schools at this time it was clear that access to the new 'modern mathematics' content became available, following the publication, for example, of the materials of the School Mathematics Project, those of the Contemporary School Mathematics Project and a small number of other textbooks. The presentation of the subject matter, however, although rather more 'user-friendly', and thus 'enhanced', was, nevertheless, more traditional than that of the Nuffield Primary Mathematics Project.

On balance, the strongest drive for modernising and reforming the mathematics curriculum in schools during this period emanated neither from Government initiatives nor from a 'trendy left' professional grouping, but principally from the public and independent school sector, which significantly had very strong links with universities and industry. Professor Geoffrey Matthews, the Director of the Nuffield Primary Mathematics Project together with Sir Bryan Thwaites, the Director of the Schools Mathematics Project and most of his writing colleagues, had attended and taught in independent schools. By contrast however, most members of the first Nuffield writing team had been seconded from LEA schools. The inspired leadership of these projects by Matthews and Thwaites was a profound source of energy at this time; moreover, it is clear that both projects, each with its own specialisation, attracted the support of many teachers in the state sector eager to develop a new approach to curriculum in mathematics.

Bryan Thwaites and Geoffrey Matthews were distinguished mathematicians with powerful connections with politicians and government ministers, the civil service and the media. Their success was even more significant in that the independent sector provided for only some seven per cent of pupils in England and Wales, yet the projects' output substantially permeated the state sector, both at secondary and primary levels. When, as happened subsequently, government again began to exercise control over curriculum, the independent fee paying schools retained management of their own curricula. The conclusion can be drawn that the rich and powerful tend to triumph under any circumstances.

The Schools Council was responsible for initiating a comprehensive agenda in curriculum development - in the context of this study, through the Mathematics for the Majority Project and its continuation. The characteristic which separated the work of the SMP and Nuffield Primary Mathematics projects from that initiated under the Schools Council umbrella was the patent dynamism of the former - still clearly epitomised today in discussions with the former Directors of these projects - and the slow progress of the latter. While there was much evidence of good intent in the work of the Government initiated Schools Council, there was also evidence of dissipation of energy - largely because of its unwieldy administrative structure and an inability to evaluate its project activity and to plan outcomes. Such dissipation was exacerbated by an interpretation of a clause written into paragraphs six, 19 and 22 of the Schools Council's constitution, that 'schools should have the fullest possible measure of responsibility for their own work, including responsibility for their own curricula and teaching methods'. Essentially this gave teachers the right to accept or reject any curriculum development initiative; a large number chose the latter option.

There was considerable variation in the success or failure of mathematics projects of this period. Some, such as the Midlands Mathematics Experiment and the Shropshire Mathematics Project, whilst promoting innovative new curricula, lacked a critical mass to sustain penetration of the market long term. The organisers did not have the means, nor yet possibly the wish, to circulate their materials more widely. The need to have a critical mass to succeed was a general point relating to implementation of curriculum initiatives which was made in evidence by four educators of the 1960s.

Three other educators indicated that the measure of success or failure of an initiative was closely linked to teachers' requirements in carrying out their daily duties in a busy professional life. In this context, the School Mathematics Project was the most successful. It achieved immense popularity and fired the imagination of many teachers of mathematics at the secondary school stage. Clearly efficient management and the quality of intellectual leadership were important factors in its success, a conclusion which it is important to bear in mind in planning for curriculum change in the year 2001 and the future. SMP significantly changed the face of mathematics teaching at secondary school level throughout England and Wales during the ten years from 1964 and continued to have a substantial influence for the next 35 years, evidenced by the presence today in the Institute of Education Curriculum Resources Library of SMP books published as recently as 1996. A key element lay in its completeness, providing texts which furnished a ready-made two, three or five year course for pupils, together with associated teachers' handbooks. Examination Boards provided GCE 'O' and 'A' level examinations linked specifically to the SMP mathematics courses.

The materials of the School Mathematics Project were not, however, universally popular. Negative views came from some teachers, university lecturers and some industrialists, the last being concerned at the omission in the materials of activities involving basic practical mathematical operations. Older members of the Mathematical Association were said to have received the SMP proposals unenthusiastically.

The Nuffield Primary Mathematics Project achieved its aim of persuading a large number of teachers to accept the changes in the teaching of mathematics recommended in the guides. It was very popular. Extensive communication between Professor Geoffrey Matthews and the author in recent years has added an important new dimension to the study of how changes in curriculum content and teaching methodology were introduced in primary stage mathematics in the 1960s and 1970s in England and Wales.

A key element in the Project's success was the contrast between the attractive, exciting new content, together with informal methodologies of teaching proposed by the Project, and the traditional arid curriculum content and didactic teaching which preceded it. In evidence to the Plowden Committee, HMI confirmed that a substantial minority of primary schools had changed their approach to mathematics teaching as a consequence of exposure to ideas generated by the Nuffield Project and by other initiatives, including the pioneering work of HMI Edith Biggs. Although the Project, except in one small area of activity, did not provide pupil materials or textbooks, it did trigger the publication of a number of books which filled this gap, the most popular being Harold Fletcher's series *Mathematics for Schools*, first published in 1970, to which unsolicited positive reference was made by a number of educators at interview. The issuing of the *Checking-up* Teachers' guides was significant, since they represented a first attempt to gauge a child's fundamental understanding of a mathematical concept. These guides did not meet with complete approbation, not least because of the time each check-up took for a teacher to administer, but they laid the foundations for a later, much acclaimed, series, with similar intent, published by the ILEA Inspectorate in 1978 and entitled *Checkpoints*, implemented, within the author's knowledge with enthusiasm, both in the ILEA and elsewhere.

The Project had some significant flaws which militated against a complete acceptance of its tenets and output. The failure to provide an intellectual infrastructure for its ideas left teachers unsupported and vulnerable to attack, when they accepted without question the Project's philosophy that practical activities and the discovery approach would of themselves produce opportunities for mathematical understanding to be generated. Many teachers remained unconvinced by the Project's argument that the direct teaching of basic skills was unnecessary, and continued to do so.

The Project encouraged the implementation of 'discovery methods', both in class and in the local environment. 'Hands-on' experience for pupils in the infant, junior and lower secondary sectors was strongly supported by the interpretation which was placed upon the conclusions of Professor Piaget, especially by college of education lecturers, who held that the acquisition of mathematical concepts contributing to intellectual development was facilitated by the handling of materials. The Plowden Report of 1967 sustained this view and neglected the need for systematic programmes of teaching which would lead to the mastery of basic mathematical skills.

Time devoted to group and individual practical activities in class often reduced the time formerly set aside for the teaching of basic mathematical skills and drills. Under the influence of the suggestions for 'hands-on' experience for pupils, which were profusely illustrated in the Nuffield Project's Teachers' guides, a large number of teachers allowed the need for formal teaching of skills to decline in importance and, more seriously, did not appreciate the significance of this decision. There was a belief, naive in character, that such skills would be acquired naturally as a result of discoveries by children in their practical activities. Regrettably, in the author's experience, teachers were not, on the whole, disabused of this view by those responsible for in-service or pre-service training, for example, members of the Project team or college of education lecturers. As a result, for a substantial number of pupils at school during this period, the facility of quick recall of routine facts in number and measurement was downgraded, as was the ability to apply this information in a wide range of contexts - a useful tool in everyday life. This view was echoed by a former headteacher of the time who felt that children had spent too much time on discovery work at the expense of skills training. Present government policies have acknowledged the seriousness of this potential deficiency by requiring teachers to instigate a numeracy hour each day. Government has also begun to question the previously accepted norm of group and individual work and promoted the re-introduction of whole class teaching at some time in the school day. In contrast, a positive view of the investigatory nature of discovery activities was expressed in evidence by three educators who noted that, concurrently, children were beginning to learn how to carry out in-depth research of a topic, a skill they had lacked hitherto. These observations point up the need for further research into the efficacy of these two methods of learning, or into the application of a combination of both.

An important consequence of the setting up of the Nuffield Project was the requirement for LEAs to establish and maintain teachers' centres in every area where the Project was active.Teachers' participation in in-service courses in mathematics which involved workshop activities not only promoted their greater understanding of mathematical relationships but strongly contributed to defusing the fear of the subject which many had felt since their childhood.The following years saw the remit of the teachers' centres, or professional development centres as they were ultimately described, widened to embrace the whole range of curriculum activity at primary, secondary and occasionally at post secondary school level.They became a fundamental element of in-service training and further professional development. Six educators, in their evidence, stressed their importance, located as they were in dedicated accommodation, with provision of adequate human and material resources, in that they addressed the immediate curriculum development needs of a large number of teachers. The centres had the potential to generate curriculum change across the whole teacher population but it is important to note that no teacher could be compelled to attend a course, whether in or out of school hours. In consequence, the results of in-service training initiatives were unpredictable and the scale of the application of the end product patchy. It has been noted by several writers that the quality of the few evaluation exercises carried out in relation to curriculum initiatives of the time was generally poor; research for this thesis reinforced this conclusion. Equally significantly, a major deficit was observed in the lack of systematic follow-up with teachers in school of in-service training courses, the effect of which was seriously to detract from their potential impact. One former headteacher expressed the view that although teachers' attitude to in-service training was generally positive, the quality of the in-service training itself was uneven.

Educators who had provided or taken part in in-service training in the later 1960s and 1970s pointed to a powerful feature of professional support for teachers which was initiated during the 1960s and continues to the present time - the utilisation of the media for training and publicity purposes. The Nuffield Primary Mathematics Project was supported by the making of three films depicting mathematical activities in both primary and secondary schools, whilst the BBC (and later the ITA) provided substantial help through the provision of television series illustrating children's mathematical activities. Elsewhere, SMP's Bryan Thwaites followed a different course in raising awareness of the impact of the shortage of mathematics teachers in schools and the need for curriculum reform through his regular contacts with the press, notably *The Times*, and with members of the two Houses of Parliament, where his arguments were received with respect.

The Nuffield Project was recognised internationally. Teachers in developing countries who were addressing the task of curriculum renewal in mathematics were helped by the production of two books, published jointly by the Centre for Educational Development Overseas and the Nuffield Foundation, which contained a distillation of the philosophy and practice set out in the original Teachers' guides. Equally the materials of the School Mathematics Project, sometimes in modified form, were to be found in overseas countries, most particularly in Africa. The impact of both these projects was initially considerable, but nevertheless short-lived, principally because some government leaders were not convinced of the value of the study of 'modern mathematics', preferring instead for students to have exposure to traditional mathematics topics, some of which had immediate applications in agriculture, commerce and industry, a conclusion underlined by the author's professional experience of curriculum change in the late 1980s and early 1990s, in Africa, India, Indonesia and Malaysia.

The Teachers' guides of the Schools Council Mathematics for the Majority Project were in the vanguard of curriculum development and were comprehensive, ambitious in scope and relevant to everyday life. The Project's arrival was timely; it endeavoured to raise teachers' level of mathematical knowledge and awareness, provided ideas for children's activities and anticipated the curriculum needs associated with the raising of the school leaving age to 16 in 1972.The Project encouraged the development of cross-subject and inter-teacher collaboration, a new concept in the 1960s. In particular, the work of the Project in focusing on curriculum provision in mathematics for pupils of *below* average ability must be commended. Further research into their needs was undertaken by Brenda Denvir and the results published as a Report by the Schools Council in 1982.

Nevertheless, research for this thesis indicated that this Project was the least successful of the three reviewed. It relied almost entirely on Teachers' guides to disseminate its ideas; it had no clear strategy for their overall implementation, nor yet an intellectual infrastructure in which the ideas could be embedded. It experienced serious logistical and dissemination problems almost from the beginning, which prevented schools from accessing the materials until late in the life of the Project. Essentially, it lacked efficient management. The limited, or occasionally non-existent, mathematical training of many teachers, coupled with the poor basic knowledge and jaundiced attitude of many of the targeted pupils, raised formidable barriers to effecting improvements. Evidence suggests that the intellectual goals and the practical objectives set out by the MMP were too high for most of the targeted students.

The materials of this Schools Council Project never had a guarantee of acceptance or implementation, because teachers held the responsibility for choice of curriculum content and methods of teaching. They could choose to accept and implement the materials in full, to select items which were useful to them, or to ignore the initiative completely. Many chose the last. The greatest impediment to the successful implementation of the Project was the lack of support from the senior mathematical establishment, which was clearly more interested in the production of materials for academic pupils, rather than for pupils of average and below average ability. It was particularly unfortunate that the potential support which elements of the Mathematical Association's Report *Mathematics Eleven to Sixteen* of 1974 could have given arrived too late in the market to have much of an impact.

The fundamental ideas of the Mathematics for the Majority Project led to the later development of mathematical topic packs by its continuation project (MMCP), utilising improved procedures with teacher groups which enabled the precise requirements of pupils and teachers to be identified and met. Indeed the methodological approaches of MMP and MMCP can be seen as precursors to the SMILE initiative, some ten years later, while the concept of 'breadth of study' in the National Curriculum could be said to have its beginnings in the aims and objectives of the Mathematics for the Majority Project, a view strongly canvassed in discussion with an educator working in schools in the 1960s, who became a project writer and later still an LEA Director of Education.

Apart from the activities of the Bourbakists and the American university mathematicians, much of the credit for raising perceptions of the need for change in mathematics curriculum and in pedagogy in England and Wales can be given to two reports published by the Mathematical Association, *The Teaching of Mathematics in Primary Schools* (1955) and *Mathematics in Secondary Modern Schools* (1959). In respect of the primary school, compelling arguments for pedagogical change were advanced by HMI Miss L D Adams in *A Background to Primary School Mathematics* and in her Presidential address to the Mathematical Association in 1960. HMI Edith Biggs substantially improved mathematics teaching in schools through the medium of her nation-wide, in-service training courses for teachers, headteachers, advisors and inspectors in the early 1960s and through the publication of her Schools Council Bulletin *Mathematics in Primary Schools* in 1965. Her dynamic approach was matched, in their different ways, by three of her colleagues - Robert Morris, Robert Lyness and Arthur Rollett - and by the efforts of contemporaries such as Brian Young, Director of the Nuffield Foundation from 1964 to

1970, together with Bryan Thwaites and Geoffrey Matthews. Staff in university departments and colleges of education gave strong support to curriculum development initiatives in many subjects, including mathematics, focusing on improving content and on changing methodologies of teaching, through their participation in in-service training courses for teachers, through the medium of professional courses for pre-service students, and through their writing. College of education staff, in contact with large numbers of pre-service teachers who would shortly enter schools, were particularly influential in initiating many of the changes, especially in pedagogical practice, which were seen in schools in the late 1960s and 1970s.

There was only limited evidence from the educators of the 1960s and 1970s that the projects of this time had any marked effect on mathematics teaching. A small number (three) specifically condemned Schools Council activities as either amateurish, unstructured, unsustained or misdirected. However, one important by-product of curriculum development initiatives during this period noted in evidence by six educators was the achievement of an enhanced professional status for teachers as a consequence of their large scale participation in project activities and in-service training where they took advantage of the freedom to innovate and devise new curricula, to think about children's needs and how they learn, and to develop 'ownership' of programmes which they themselves had devised. A teachers' centre leader and project writer succinctly stated that the ultimate consequence of the enormous energy at work in this field at the time was not so much seen in curriculum development, but rather in teacher development

The process of organising and delivering training in mathematics at the newly created teachers' centres, of participating as leaders on HMI Edith Biggs' and similar courses, of acting as classroom researchers, and of the writing of textbook materials and journal articles, resulted in the creation of a substantial minority of headteachers and teachers who could offer informed judgements and practical assistance about implementing curriculum development. Membership of Schools Council committees and participation in its projects as writers or field officers widened teachers' professional knowledge and gave them first hand experience of the principles and practice of curriculum development.

This was noted as a valuable asset by four educators of the 1960s and 1970s, a development which continues to flourish in a more general sense at the present time.

It is clear that the three projects of the 1960s and 1970s examined in this thesis, the materials they produced and the thinking which informed pre-service and in-service training courses of the day, all, in their different ways, stimulated a variety of long term changes in the content and the methods of mathematics teaching and learning, in the assessment of mathematical understanding in pupils, and in concurrent improvements in teachers' professional skills and expertise through their involvement in curriculum development initiatives. Curriculum development was and is subject to many influences, some of a professional, others of a personal nature. Understanding the variety of elements, such as the beginning of the space age, the ending of the 11+ examination, the move to raise the school leaving age to 16, and the growing disenchantment of parents and politicians with traditional curricula and its teaching, all of which had a bearing on the implementation of the mathematics projects in the 1960s, permits a greater understanding of the emphases in mathematics teaching and learning which are apparent in schools today and of the history of their development. The evaluation of the positive and negative features of three important mathematics projects of the 1960s together with other initiatives of the time, as has been attempted in this thesis and synthesized in this chapter, will provide information to curriculum planners of the present and the future to perform a more efficient function in introducing new content and in creating new methodologies of learning mathematics.

A great deal of human and financial resources was expended, sometimes in a profligate manner, in implementing the mathematics projects of the 1960s. Despite this, a considerable number of teachers remained largely unaffected, either through a disinclination to be involved in such initiatives, or through apathy or a lack of information. Lessons need to be learnt from an appraisal of the projects' successes and failures and the manner of their implementation, and applied to any modern curriculum development initiative. Individual or collective enthusiasm for curriculum change such as was observed in the 1960s and 1970s can be commended, but within contemporary

English educational culture, any new proposal in this context should be evaluated for its potential benefits on a number of assessments, generated, through consultation and cooperation, by all who will be concerned in its development, delivery and reception. These might include government departments and associated funding bodies together with those charged with monitoring curriculum, mathematicians, teachers in class, students and their parents, educational planners, project managers and financial controllers. In consequence all these participating agencies and individuals would develop a measure of corporate ownership of the proposal. Subsequent to its acceptance and successful trials, materials would be distributed on a wider scale and extensive in-service training organised for all teachers who, under present government control, will be required to deliver the new curriculum. This is not to suggest that results of such a developmental sequence could be determined in much less than the lifetime of the majority of the projects of the 1960s and 1970s - in education there is a long lead-in time before results begin to show - but a cohesive approach to curriculum development such as described above would tend to ensure that financial and human resources would be targeted in a much more efficient and successful manner than 35 years ago.

Appendix A : Teacher Training College Reading List: October 1969

UNIVERSITY OF LONDON GOLDSMITHS' COLLEGE

INFANT DEPARTMENT

CURRICULUM COURSE

MATHEMATICS IN THE INFANT SCHOOL

The course on mathematics will contain the following elements - a lecture course followed by tutorials and workshop experience, practical work with children and individual study as organised on the sheet included.

Lecture 1. Pictorial Representation.

2. Matching, comparison, seriation, sets and relations.

3. Provision for conceptual development.

4. Shapes.

5. The concept of number.

6. The use of the environment.

Each lecture will be followed up by workshop experience and will require each student to have scissors, pencils, rulers, coloured felt tip pens.

In the summer term there will be an introduction to metrication and simple statistics together with preparation of materials for use in school on Final Teaching Practice.

Bibliography

Counting and Measuring:	E. Churchill,	R. Kegan & Paul
Background to Mathematical Development	D. Lee.	
The Growth of Basic Mathematical and Scientific Concepts in Young Children.	K. Lovell,	U.L.P.
The Child's Conception of Number	J. Piaget,	R.K. Paul
Mathematics and the Conditions of Learning	J.B. Biggs,	N.F.E.R.
The Language of Mathematics	F. Land,	John Murray
Teaching of Mathematics in the Primary School	Mathematics Association, Bell & Sons.	
Pictorial Representation; Beginning; Mathematics Begins	Nuffield Foundation	
Number	T. Smith	
How and Why Do We Learn?	W.D. Wall,	Faber

Particular Methods and Materials

Stern C.	Children Discover Arithmetic	Harrap
Materials - E.S.A. - Harlow		
Cuisinaire C. & Cattegno, C.	Number in Colour	Heinemann
Materials - The Cuisinaire Co. Reading.		

Materials etc.	E.S.A.	Harlow
Sealey, L.G.,	Creative Mathematics in the Junior School	B. Blackwell

Unifox Materials & Manuals
Philip & Tacy, Hugh St. London, S.W.6.

Series - to be added to from you study of texts.

Flavell & Wakeham	- Primary Mathematics Series.	Methuan
Marsh, L. Ferrier, W.	Real Life Number -	Arnolds etc.

E. STOCKBRIDGE

28.10.1969.

Appendix B: <u>Educators and students of the 1960s/1970s interviewed</u>

Occupation in the 1960s/1970s	Present/recent occupation
Student	Officer, International Support Agency
Student	College Lecturer, University
Student	LEA Education Officer
Student	Primary School Headteacher
Student	College Senior Lecturer, University
Student	Sales consultant, motor industry
Infant school teacher	Infant school Headteacher
Primary school teacher	LEA Primary school inspector/ OFSTED Registered Inspector
Primary school teacher	College Senior Lecturer, University
Primary school teacher	University Professor, mathematical studies
Primary school headteacher	University Professor, mathematical studies

Primary school headteacher	Director LEA Education Management Unit
Middle school headteacher/teacher trainer	University lecturer/researcher/writer
Secondary school teacher	Director, University Institute of Education
Secondary school teacher	Headteacher secondary school
Secondary school teacher	Her Majesty's Senior Chief Inspector
Secondary school teacher	Director, LEA INSET Unit
Secondary school teacher/project writer	Director, LEA mathematics centre
Secondary school teacher	Senior HMI
Secondary school teacher/project writer	LEA Director of Education
Secondary school teacher/project Director	University Professor, mathematical studies
Secondary school teacher/writer	University Professor, curriculum studies
Secondary school teacher	Director, Social Education Support Unit

Teacher educator	Director Commonwealth Liaison Agency
Teacher educator/writer	Professor of Education; Director, Higher Education College
Teacher educator	Professor, History of Education, University Institute of Education
Teacher educator	SeniorLecturer/researcher,University Institute of Education
University lecturer/project Director	University Vice Chancellor
University lecturer/researcher	University Vice Chancellor
Commonwealth teacher	Senior international education adviser, British Council
Government Officer, overseas service	Chief Education Adviser, ODA
Her Majesty's Inspector	Senior HMI international affairs
Her Majesty's Inspector	Senior HMI, CSG & Schools Council Officer
Officer, Centre for Educational Development Overseas (CEDO)	Senior British Council Officer
BBC producer, educational programmes	Senior BBC producer, educational programmes

Appendix C: Nuffield Primary Mathematics Project, First Writing Team

Members	Post from which seconded
Dr. G. Matthews (Organiser)	Deputy Head and Head of Mathematics Department, St. Dunstan's College, Catford, London, S.E.6.
Miss B. M. Mogford	Lecturer, Goldsmiths' College, London, S.E.14.
Miss B. A. Jackson	Deputy Head, New City Primary School, London, E.13.
Mr. J. W. G. Boucher	Mathematics Department, Devonshire Junior School, Blackpool, Lancs.
Mr. G. B. Corston	Head Master, George Tomlinson Junior School, Southall, Middlesex.
Mr. H. Fletcher	Inspector of Schools, Staffordshire.

Appendix D: Nuffield Primary Mathematics Project, Consultative Committee

Dr. G. Matthews,
Organiser,
Nuffield Foundation.

Mr. R. A. Becher,
Nuffield Foundation.

Mr. J. W. G. Boucher,
Nuffield Foundation.

Professor W. H. Cockcroft,
Mathematics Department,
University of Hull.

Mr. R. C. Lyness, H.M.I.

Miss B. M. Mogford,
Nuffield Foundation.

Mr. R. Openshaw,
Education Offices,
London Borough of Newham.

Mr. D. R. F. Roseveare,
B.B.C. Schools Television.

Mr. A. G. Sillitto,
Jordanhill College of Education,
Glasgow.

Mr. P. F. Surman,
Headmaster,
Chatham Technical High School for Bo

Dr. D. R. Taunt,
Jesus College, Cambridge.

Mr. F. Woolaghan,
Elaine County Primary Junior School,
Strood, Rochester,
Kent.

Professor J. Wrigley,
Department of Education,
University of Southampton.

Mr. B. W. M. Young,
Nuffield Foundation.

Appendix E: Nuffield Primary Mathematics Project, Pilot Areas

PILOT AREAS FOR THE MATHEMATICS AND SCIENCE PROJECTS

The Mathematics Project

Northumberland	- Whitley Bay area.
Doncaster	- Group of schools in an urban area of the Borough.
Staffordshire	- Kidsgrove area.
Middlesbrough	- Area on eastern outskirts of tow
I.L.E.A.	- Ladbroke area.
Newham	- Group of schools in the former West Ham area.
Cambridgeshire	- Cambridge city and neighbouring rural area.
Hampshire	- Winchester area.
Somerset	- Yeovil area.

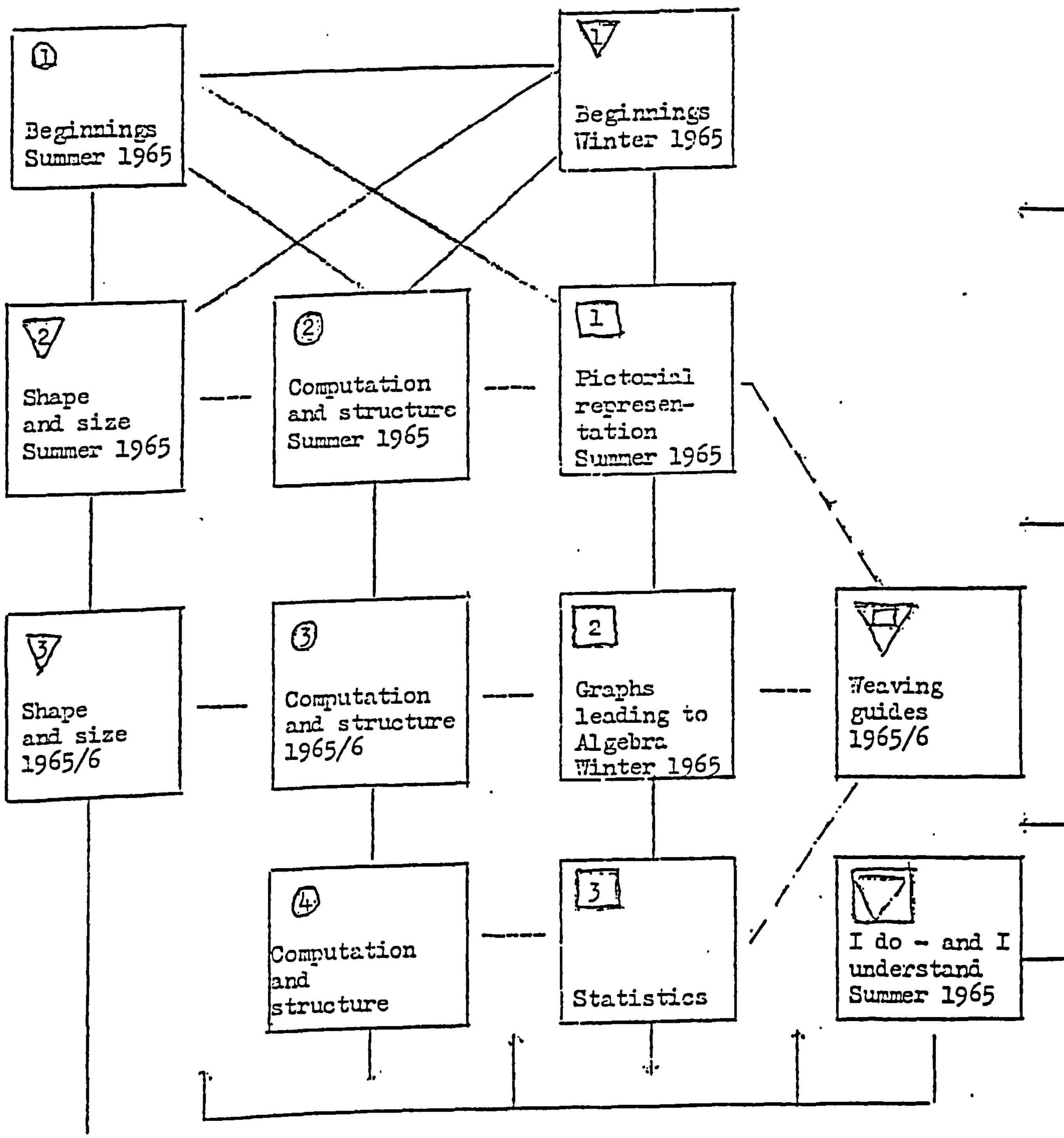
The Science Project

Carlisle	- Group of schools in an urban area of the city.
Yorkshire (West Riding)	- Skipton area.
Liverpool	- Gateacre area.
St. Helens	- Parr area.
Essex	- Cholmsford area
I.L.E.A.	- Norwood Area
Leicester	- Group of schools in the city.
Anglesey	- Holyhead area.

The Mathematics and Science Project

Birmingham	- Moseley/King's Heath area.
Kent	- Folkestone area.
Bristol	- Withywood and Brislington areas.
Cardiff	- Llanrumney area.

Appendix F: Nuffield Primary Mathematics Project, First writing plan



Appendix G: GCE SMP O level mathematics syllabus [42, SMP notes]

General

The emphasis in the examination will be on the understanding of simple basic mathematics concepts and their applications

Importance will be attached to clear expression and careful reasoning; candidates will be expected to understand the correct use of the signs =>, <=>
Questions requiring lengthy manipulation will not be set.
Candidates will be expected to be able to express physical situations in mathematical symbols, and to use their judgement as to the degree of accuracy appropriate to any particular problem.
Slide rules with A, B, C, and D scales, the usual geometrical instruments and an approved set of three figure trigonometrical tables with a list of formulae will be required.
Knowledge will not be required of the rectangular properties of the circle; angle bisector theorem; extension of Pythagoras; secant, cosecant and cotangent ratios. Questions will not be set explicitly on proofs of theorems and 'ruler and compass' constructions. Questions will not be set involving the solution of quadratics by formula or by completion of the square; nor on the ½ ab sinC or 's' formulae for triangles.

Syllabus

The important units of weights, measures and money, including metric units. (Quantities will not be expressed in more than two units with the exception of.s.d.)
Fractions, decimals, ratios, percentage.
Approximations and estimates, significant figures, decimal places, limits of accuracy and the use of inequality signs.
The idea of scales of notation other than the denary
The expression of numbers in the form a x 10 to the power n where n is a positive or negative whole number

The use of the slide rule

Length, area and volume: mensuration of common plane and solid figures - the rectangle, triangle, circle, cylinder, cone and sphere.

The use of Pythagoras' theorem. Sine, cosine and tangent ratios of acute angles. Solution of triangles in cases reducible to right angled triangles. Simple applications to three dimensional problems.

The notation and ideas of a set; union, intersection, complement, subset; empty and universal set; Venn diagram; the number of elements in sets and the unions and intersections of sets. (Approved symbols: $\in$, $\cup$, $\cap$, $'$, $\subset$, $\emptyset$, $\mathscr{E}$)

Locus

The use of symbols to represent numbers, sets, transformations.

Conditional and identical equations: rearrangement of formulae.

Factorisation of $ax + bx$, $a^2 - b^2$, $a^2 \pm 2ab + b^2$, simple manipulation of fractions,

$x \times y = 0 \Leftrightarrow x = 0$ or $y = 0$.

Inequalities and their manipulation. Simple and simultaneous linear equations and inequalities in not more than two unknowns. Applications of inequalities, especially to linear relationships and graphs.

Rectangular Cartesian coordinates. 2 x 2 matrices. Vectors as matrices. Matrix multiplications, the unit matrix, the formation of the inverse of a non-singular matrix and applications to simultaneous equations and linear transformations.

Relationships, especially linear, square and reciprocal, and their graphs.

The exponential law of growth. Proportion of variables related by simple power laws.

The gradients of graphs by drawing and the estimation of areas under graphs. Applications to easy linear kinematics involving the distance - time and speed - time curves and other rates of increase.

The use of graphs in linear programming.

Similarity and congruence. The geometry of Euclidean space based on the operations of reflection, rotation, translation and enlargement. Symmetry about planes, lines and points. Combination of transformations.

The circle, including the constant- angle property and tangents.

Applications of similarity including the areas and volumes of similar figures, scales and simple map problems.

Simple plans and elevations.

The earth considered as a sphere: latitude and longitude, great and small circles, nautical miles, distances along parallels of latitude and along meridians.

Simple probability. (Specific knowledge of the sum and products laws will not be required but problems on the combination of probabilities may be set).

Graphical representation of numerical data; calculation of the mean, median and quartiles.

Appendix H: Chapter titles of SMP Books A to H inclusive

Book A

Prelude: the pinboard
1. Number patterns
2. Coordinates
3. Angles
4. Number bases
5. Symmetry
6. A quick look at fractions
7. Polygons
8. Further number patterns
9. Two ways of looking at division
10. Polyhedra

Book B

Prelude: tiling patterns
1. Letters for numbers
2. Tessellations
6. Angle
7. Relations
8. Binary and duodecimal bases
3. Decimals
4. Area
5. Comparison of fractions
9. Statistics
10. Directed numbers
11. Topology

Book C

Prelude: change of position
1. Area
2. Directed numbers
3. From relation to graph
4. Multiplication and division of decimals
5. Extending graphs
6. Reflections
7. Networks
8. Rotations
9. The slide rule
10. Journeys
11. Statistics
12. Planes of symmetry

Book D

Prelude: looking at tables
1. Multiplication and division of fractions
2. Enlargement
3. Multiplication and division of directed numbers
4. Vectors
5. Punctuation and order
6. Looking at graphs
7. Ratio
8. Arrow diagrams and mappings
9. Symmetry in three dimensions
10. Percentages
11. Graphical interpretation
12. Number patterns

Book E

Prelude: filling space
1. Right-angled triangles
2. Sets
3. Matrices
4. Experiments
5. Square roots
6. Solving equations
7. Probability
8. The slide rule
9. Volume
10. Enlargement (an introduction to trigonometry)
11. The circle
12. Networks and polyhedra

Book F (Provisional list)

Prelude: flow diagrams
Matrices at work: networks
Number pattern (recurring decimals)
Statistics
Harder ratio
More solution of equations
Matrices at work: transformations

Isometries
Trigonometry (sine and cosine)
Matrices at work: relations
Formulae
Probability and solution sets
Computation and programming

Book G (Provisional list)

Prelude: shearing and stretching
Combination of isometries
Harder percentages
Trigonometry
Algebra
Correlation and lines of best fit
Matrices and transformations and their combination
Networks
The circle
Probability combined
Linear programming
The slide rule
Statistics

Book H

Chapter titles are still under discussion but will include:

Linear programming
Computation
Shearing and stretching
Loci
Matrices and transformations and their combination
Statistics
Trigonometry

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1.1.3 File papers SC 105/402/01, 1968, concerning the proceedings of the Education Board in relation to the publication and content of the Schools Council pamphlet entitled *Dialogue*

1.1.4 File Papers SC 318/440/018, 1966, concerning support for local curriculum development centres. Initiated by University of Manchester School of Education

1.1.5 File Papers SC 328/352/01, 1966, concerning the making of a film *Maths Alive* supported by DES and Schools Council

1.1.6 File Papers SC 1/352/ 011, 1967, concerning a publication about decimalisation of money, *Change for a pound*

1.1.7 File papers SC 318/353/037,1968, concerning the making of two films *Into Secondary school,* about activities in the first year of secondary school, and *Maths with everything*, about activities in the Infant school

1.1.8 File papers SC 318/352/05, 1970, concerning the Mathematics for the Majority Project and the issue of the final *News Sheet* by the Project in 1972

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1.1.11 File papers SC 76, 128/345/346/03, 1975, concerning the Working Party on mixed ability teaching in mathematics and arrangements for a conference about this issue in 1977

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1.2.6 1976, *Mathematics for the Majority Continuation Project* (MA 13 02)

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A Look Ahead - A Nuffield Mathematics Project Weaving Guide 1971

Beginnings 1967

Checking Up 1 1970

Computation and Structure 2 1967

Computation and Structure 5 1972

Computers and Young Children 1972

Desk Calculators 1967

Environmental Geometry 1969

Graphs leading to Algebra 3 1973

I do and I understand 1967

Into Secondary School: a short survey 1970

Logic 1972

Mathematics Begins 1967

Mathematics, from primary to secondary 1978

Maths with Everything 1971

Pictorial Representation 1967

Probability and Statistics 1969

Problems, Green set 1969

Problems, Purple set 1971

Problems, Red set 1970

Shape and Size 2 1967

The Story so far 1969

Your Child and Mathematics 1968

<u>The Nuffield Primary Mathematics Project and the Centre for Educational Development Overseas (CEDO)</u>

(Both the guides were published by Chambers and Murray, London)

Mathematics: the first 3 years 1970

Mathematics: the later Primary years 1972

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Algebra of a Sort 1973

Assignment Systems 1970

Crossing Subject Boundaries 1974

From Counting to Calculating 1972

Geometry for Enjoyment 1973

Luck and Judgement 1971

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