

Interrelating Science, Mathematics and Technology Education



Commonwealth Secretariat

Interrelating Science, Mathematics and Technology Education

A BASIS OF GENERAL EDUCATION FOR ALL

Education Programme
Human Resource Development Group
Commonwealth Secretariat
Marlborough House, Pall Mall, London SW1Y 5HX

COMMONWEALTH SECRETARIAT

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FOREWORD

The chapters which comprise this publication are based on a set of the papers, commissioned by the Commonwealth Secretariat in 1982 on various aspects of science, mathematics, technical and vocational education. Their underlying theme is the interrelationship between science, mathematics and technology education as a base for general education for all students at school level. So often in the past and, indeed, at present, the teaching of science, mathematics and technical/vocational subjects has been largely a preparation for the next stage of formal education. Such teaching has ignored the needs of the majority of children whose school education should prepare them for the world of work and for life in general. Owing to the limitations of educational systems in so many countries, little progress has been made towards adapting general school curricula and teaching styles to the needs of the majority of school children.

The chapters attempt to suggest possible strategies, based on experience in a number of Commonwealth countries, for achieving the interrelation of science, mathematics and technical and vocational subjects. We would welcome feedback on them from readers.

The Commonwealth Secretariat is grateful to the authors of these papers and to Mr. D. G. Chisman, through the Commonwealth Association of Science, Technology and Mathematics Education (CASTME), for editorial assistance in preparing for publication some of the chapters in this book.

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INTRODUCTION

The importance of science, mathematics and technical/vocational education to national development has been recognised by successive Commonwealth Education Conferences. Actions to implement recommendations from these Conferences have been a notable feature of Commonwealth co-operation in education.

The Seventh Commonwealth Education Conference held in 1977 recognised the rapid developments taking place in the approaches to and content of science, mathematics and technical subjects. As the Conference pointed out, these developments make it expedient for member countries to discuss and review curricula and teaching techniques at all levels of the educational system. Two years later a meeting of Senior Education Officials, drew attention to the affinity between science, mathematics, and technical and vocational training, and stressed the advantages to be gained by linking science and technology subjects in a Commonwealth Specialist Conference (a Commonwealth meeting at which a major professional educational issue is studied in depth and appropriate recommendations formulated). This view was shared by the Eighth Commonwealth Education Conference (8CEC) held in 1980 which recommended that: "the next Specialist Conference should be designed to review the experience of member countries in devising curricula that draw upon the subject matter of science, mathematics and technical and vocational subjects with a view to enabling the generality of boys and girls to profit from the study of these subjects both for their personal development and as a preparation for the world of work. It further recommended that this Specialist Conference should be preceded by two interrelated meetings of experts who would identify issues in preparation for its work programme."

Interrelated Meetings of Experts

In response to the 8CEC recommendation, the Commonwealth Secretariat organised two interrelated planning meetings of experts in Cyprus from 22-26 March 1982. The meetings were jointly opened formally by H. E. Mr. Nicolaos Konomis, Minister of Education of the Republic of Cyprus and met at the Philoxenia Hotel, Nicosia. They had the following broad objectives:

- (a) to identify issues relating to (i) science and mathematics education and (ii) technical and vocational education which should be considered by a pan-Commonwealth Specialist Conference;
- (b) to study the professional implications and provide guidelines for subsequent consideration by the Specialist Conference on strategies and implementation policies for the integration of these curriculum areas.

After meeting separately to address issues of (i) science and mathematics and (ii) technical and vocational education the two groups of experts met together and agreed that:

1. The education of teachers is crucial to the implementation of the proposed guidelines which demand an understanding of the relationships between science, mathematics and technology.
2. A problem-solving approach should be used so that the inter-relationships are clearly seen and used as an integrating factor.
3. Any curricula designed should make use of locally available materials so as to keep educational costs at a minimum.
4. It would be useful if the Commonwealth Secretariat would commission a study using a few topics as examples of how an interrelated curriculum can be designed and implemented. Topics suggested were measurement, resources/materials, energy, and communication.

Following this the experts divided into four inter-disciplinary groups. Each group was assigned one topic to consider how it could be taught in an interrelated way.

The following strategies were identified as contributing to the interrelationship:

- (a) The extensive use of estimation. This helps in acquiring a feeling for various measures and for understanding proportionality.
- (b) Co-operation and co-ordination between mathematics, science and technical education. This should be pursued both at the level of the teams developing curricula and at the level of school teachers. Also, it is helpful to develop a relation between primary and secondary school teachers.
- (c) Examples of various quantities given in teaching materials should be realistic and reasonable.
- (d) The collection and presentation of data in various forms.

Finally the experts urged that recommendations to be made by the Specialist Conference should be addressed to the Ninth Conference of Commonwealth Education Ministers (9CCEM) and that of the Specialist Conference should include sample professional papers as annexes.

The Planned Specialist Conference

The Government of the Bahamas kindly offered to host the pan-Commonwealth Specialist Conference in Nassau in April 1983. Unfortunately, however, it had to be postponed, and later cancelled, owing to an insufficient number of member countries indicating that they would be able to attend it. Had it been held, the Conference's* task would have been to recommend practical measures which governments could adopt to:

1. Improve the interrelation of science, mathematics, technical and vocational subjects with particular emphasis on the interaction between such curricula and the world of work.
2. Develop strategies for teacher education systems for assisting the interrelated teaching and learning of such subjects.
3. Increase local self-reliance in the provision of resources including laboratory, workshop and physical facilities used in the teaching of science, mathematics, technical and vocational subjects.

*See Appendix III for the provisional agenda.

4. Identify forms of bilateral and multilateral co-operation to support the implementation of interrelated science, mathematics, technical and vocational education curricula.

In preparation for the Conference, the Commonwealth Secretariat commissioned ten working papers. They were prepared by authors from all regions of the Commonwealth, several of whom had participated in the experts' meetings in Cyprus.

Following the cancellation of the Conference, two of the papers were modified for use as working papers at the Africa Regional Workshop on Communication in Science, Technology and Mathematics Education.*

These two papers have been revised for the present volume (see chapters 1 and 3) and appear with five others originally prepared for the planned Specialist Conference (and also used as a background document at the workshop in Malawi). All seven are presented in this volume with the hope that member countries can use them as a basis for discussion and follow-up work in the field.

*This workshop, in Blantyre, Malawi from 9-13 April 1984, was organised by CASTME with funds provided by the Commonwealth Fund for Technical Co-operation of the Commonwealth Secretariat and by the Commonwealth Foundation. It was originally planned as an in-depth professional meeting to follow-up the topic of "communication" planned to be discussed at the Specialist Conference. In the event, the workshop programme was designed to achieve an independent and a more comprehensive treatment of communication in science, technology and mathematics education and the teaching of the subjects in an interrelated way. With the exception of the Seychelles, all Commonwealth countries in the Africa region were represented.

CHAPTER 1: CLASSROOM COMMUNICATION IN SCIENCE, MATHEMATICS
AND TECHNICAL/VOCATIONAL SUBJECTS

B. J. Wilson, L. Dawe* and J. Taole*

The Scope of this Study

Communication is at the heart of the educational process. It takes many forms. Some are interactive, as in an enlightened teacher-pupil relationship. Others are one-way, as in reading a book. This study is concerned with two issues which underlie most forms of classroom communication, whether they are interactive or one-way. These issues are language and perception.

The paper begins with linguistic problems encountered at school level in the teaching and learning of science, mathematics, technical and vocational subjects through the medium of English as a second language (ESL). This is followed by a consideration of perceptual difficulties. Section 2 of the paper deals with language problems. An attempt is made to classify them, with illustrations from a variety of member countries from different regions of the Commonwealth. Although the term 'case-study' is used, limitations of space mean that much reference has had to be made to source documents and only a few salient features of each can be summarised. It is hoped that the bibliography will facilitate a much more detailed sharing of experience.

Perceptual difficulties are similarly considered in Section 3, again illustrated by a variety of case-studies. And in Section 4, a number of proposals are made with the view to motivating all concerned to increase their efforts to alleviate some of the problems in member countries.

*Contributing author

Although language and perception are considered separately in this paper, recent research evidence suggests, particularly in bilingual people, a very close relationship between the two themes. Further studies indicate that this link can be understood in terms of laterality in the brain. (Glennon, 1980; Dawe, 1982; Albert and Obler; 1978; and Kessler and Quinn, 1980).

SECTION 1

Linguistic problems: Introduction

Does language develop to communicate pre-existing thought, or is thought restricted by the verbal language available? The relation of language to thought, and hence to the learning of science, mathematics and technical subjects, is a very complex issue, which, despite much research effort, is essentially unresolved. Nevertheless, in recent years there has been rapidly growing awareness world-wide that many problems in the teaching and learning of science, mathematics and technical subjects are linguistic, rather than conceptual, in origin (Austin and Howson, 1979; Wilson, 1981).

The nature of a language, in its syntax as well as in the range of its vocabulary, is important in its ability to carry the burden of use as the medium through which a particular subject is learned. For example, the language of a less technological society may well have only limited capacity to act as a medium for scientific ideas, yet may be richly endowed for the teaching of literary, artistic and religious subjects within its own culture. Some countries attempt to draw on these strengths by adopting a policy of teaching some subjects in one language and some in another. Among Commonwealth member countries, however, this practice is not common, it being more usual to specify a level of school at which any change in the medium will occur for all subjects.

A majority of Commonwealth citizens learn science and mathematics through the medium of ESI* at some stage of their lives, whether during the primary years of education or at a higher level. In this respect they have the advantage that English has well developed science and mathematics registers. Those who study technical subjects have perhaps a greater advantage, in that internationally English terminology is increasingly becoming the standard. However, there are a variety of problem areas facing such bilingual learners; these are discussed below.

*English as a Second Language

SECTION 2

Problems inherent in learning these subjects through English.

Such problems are, of course, shared with monolingual learners. They include the verbosity and imprecision of English compared with the notations of science (e.g. verbalise the information contained in $\text{Na}^+(\text{aq}) = \text{NaCl}(\text{s})$, the wide range of English formulations of a single mathematical or scientific statement (e.g. how many ways are there of expressing $5 - 2 = 3$ in English?) and the occasional ambiguity (e.g. the failure of English to distinguish between the inclusive and the exclusive 'or'). Recent developments in the methods and materials used in the classroom and laboratory have placed greater demands on a pupil's ability to read with understanding. Although formidable, such problems are not the specific concern of this paper.

Inadequate knowledge of English. This is the problem which is likely to be most immediately obvious to the teacher. If a pupil does not understand what is said by the teacher or what is written in the textbook, he is not going to learn the subject-matter that is being presented. More dangerously, he may only partly understand, or misunderstand. The conditions and qualifications which are an essential part of much of science and mathematics may elude him, and false concepts may be formed in his mind to wreck havoc at a later stage.

For many second language learners English is an extremely difficult language to use for deductive reasoning. What Bruner (1975) calls the 'elaborate use of language' makes possible the attainment of an analytic competence which permits one to think in an abstract, hypothetical fashion. In this way language becomes an actual tool of thought. It is likely that many children, particularly ESL learners, never reach this level. In the secondary school verbal-logical thought is central to much classroom teaching. This is a particularly difficult stage for children learning in a second language, even when they have surface fluency in the language. The problems are most acute in the early years after the transition from mother tongue to English and yet relatively little work appears to have been done on the problems prevalent at that stage.

Inadequate mastery of the mother tongue. At first sight, it may be thought that the mother tongue is barely relevant to learning through ESL. However, recent research (Dawe, 1982 and 1983) has indicated that, far from being irrelevant, mastery of the learner's first language has a significant effect on his ability to reason deductively in English, and thus on his capacity to master science and mathematics through ESL. This finding, which is corroborated by other research currently in progress, has important implications particularly for the early primary years. It is noteworthy that Zambia, as part of the language policy whereby English is the medium throughout the school system, lays special stress on the teaching of local languages in the early primary years (Chimuka and Zulu, 1974).

A particular problem arises where use, and therefore mastery, of the mother tongue is positively discouraged, by parents, by teachers or by social pressures. For example, both in Jamaica and in Britain, the Jamaican Creole is not recognised as a language in its own right; rather it is considered merely as an inferior dialect of English (Dawe, 1983). This attitude is thought to be a major reason for the learning difficulties generally experienced in British schools by pupils, particularly boys, of Jamaican background. Additional difficulties also arise when the mother tongue has no written form, or when the written form is rarely used.

A lack of congruence between English and the mother tongue. This can apply to both vocabulary and to syntax. Vocabulary is the more obvious, and is probably of greatest relevance in science. However, it is the more easily remedied, since the pupil can fill the gaps in his first language by incorporating the English word e.g. 'burette', 'quadratic', 'lathe', etc. Syntactical problems are much more resistant to solution. A particularly crucial issue is that of "logical connectives". Science, and particularly mathematics, depends for its accurate verbalisation on the precise expression of a wide range of relationships, each requiring a specific grammatical formulation: A is greater than B; if p, then q; some C's are D's; x if and only if y. Yet, many languages of the Commonwealth lack such logical connectives. Dawe (1982) has shown that bilingual (ESL) children in British schools fell far short of their monolingual peers in a test on logical connectives in English. Furthermore, logical connectives was the single most important factor differentiating children's performance on a test of mathematical reasoning, accounting for over one-third of the variance.

This lack of congruence between a pupil's first language and the medium of education can have devastating effects during the years when his mastery of the medium is far from perfect. He will be forced into inter-translation to and fro between the two languages, and the greater the incongruency, the greater the resultant misunderstanding. One implication is that it is not

enough for educationalists to study problems of learning science and mathematics through English; they must also analyse the learner's first language to identify vocabulary and syntactical differences that are likely to impede understanding during the inter-translation phase of his linguistic development. The work described in the Lesotho case-study quoted below is an example of what can be done. Further, teachers of mathematics and science should explicitly teach the meaning of logical connectives within the overall registers of their subjects. (UNESCO, 1974; CASME, 1975).

Rote-learning. Inadequate knowledge of English forces many pupils into rote-learning. This strategy may pay short-term dividends, but its longer-term effects on a proper understanding of science, mathematics or technology are almost wholly detrimental. A fuller analysis of these areas of difficulty may be found in UNESCO (1974) for mathematics and in Strevens (1976) for science.

Case Studies

The case studies which follow are drawn for member countries which vary greatly in cultural and linguistic circumstances. In each case, however, the use of ESL is a major issue in the learning of science and mathematics. Nearly all Commonwealth countries are concerned with this question, and several others could have been quoted had space allowed; see, for example, Sinha and Das (1982), Reed and Wainman (1978), CASME (1975).

Case-Study L1: Australia. There are substantial immigrant communities in some cities in Australia. Many retain their own language for use in the home, so children in schools are learning through ESL. An interesting study has been undertaken in Melbourne on the general problem of digit reversal (i.e. the error made by a child who writes 51 for 15 and so on). Although this error occasionally occurs with larger numbers, it tends to be more common with numbers in the teens, i.e. 13 to 19. The common explanation is that children are not familiar with how the place-value system works; by the time they are dealing with numbers in the twenties and beyond, they have mastered it. The Melbourne research shows, however, that the origins of the difficulty are linguistic rather than notational or conceptual.

The learning of science and mathematics by Aboriginal people has also been studied. Harris (1980) has analysed the mathematics and scientific registers of several Aboriginal languages, and demonstrates how these are being supplemented to meet the requirements of living in a setting that places more commercial and technological demands on their speakers than did the traditional way of life.

Case-Study L2: Britain. Britain has a large number of children of immigrant families in its schools. Even those children born in Britain of immigrant parents may find themselves in an ESL situation when they arrive at primary school, as many immigrant families retain their mother tongue as the language of the home. The linguistic complexity, even where a relatively small number of mother tongues are represented in any one school, puts enormous demands on teachers.

Various research studies have been undertaken. Among the most significant is that by Dawe (1982, 1983). Major conclusions include:

- (a) The development of the ability to use logical connectives for reasoning and argument is an important task for teachers of science and mathematics; it needs far more explicit attention than it is often given.
- (b) The maintenance and mastery of a child's first language needs to be taken seriously as a means of developing the cognitive flexibility of bilingual children.
- (c) Bilingual children regularly switched languages in mathematics lessons. A number of things could prompt a language switch: a difficult question asked by the teacher, a desire to communicate with a friend without being thought stupid for asking a simple question, a problem with the meaning of a written task, an emotional response to give security in a threatening situation, advice from a parent etc.

The phenomenon of language switching is a particularly difficult problem in classroom communication if the teacher is unaware it is going on. If a child translates a question from a teacher into his first language (L1), extracts the meaning, carries out the reasoning in L1, obtains an answer, and finally translates back into English, there are obviously a great many possibilities for error. The child's response may give the teacher the impression the child is dull or weak in mathematics. Unfortunately, the possibility of dealing with language switching when it is known to occur can only be effective if the teacher is himself bilingual.

Another important finding relates to a much earlier stage of development. Thus in the case of Asian children, research has confirmed a consistent and marked improvement in cognitive abilities with years of schooling and exposure to British culture (Little, 1975). However, not all the tested abilities seem equally affected. Thus Indian children, mostly Punjabis in the studies cited, show marked progress on a range of verbal abilities but not on spatial and perceptual abilities (Ghuman, 1975). This has been observed also among West Indian children (McFie and Thompson, 1970).

Case-Study L3: India. One of the first problems that a child faces on starting primary school is getting to grips with the number system, in both symbols and words. Some languages of the Commonwealth have lengthy and complex ways of verbalising larger numbers, and the impression given to the child, that mathematics is complicated and difficult, may determine his attitude to the subject throughout his life. One such language is Gujerati. Recent work has been undertaken to simplify the number words from 1 to 100, and research has demonstrated that young children master the new system more easily than the traditional system (Soni, 1982). This work was awarded First Prize in the 1982 CASTME (Commonwealth Association of Science, Technology, and Mathematics Educators) Awards Competition.

Case-Study L4: Lesotho. Attempts to deal with the problems of teaching science and mathematics go back a long way in the history of Western-type education in Lesotho. The August 1940 issue of the Lesotho (then Basutoland) Teachers' magazine suggested that the correct Sesotho names for numbers such as six, seven and nine should be used in school, instead of the adapted names, "sekese" for six, "sebene" for seven and "naine" for nine. It appears, however, that this call was not successful. Thus, for example, the word 'half' is translated into Sesotho by a phrase which means something like 'one from two'. This is not the intended meaning, and the phrase is gradually, even though unofficially, being replaced by the coined word 'halofo'. Apart from the issue of proper Sesotho number names, there exists a serious lack of standard equivalents for many mathematical terms. However, a modest start has been made towards the creation of a glossary of mathematical terms used in the primary school.

At the secondary school level, the problem of finding vernacular equivalents does not arise. English is the sole medium of education. It is generally assumed that at this stage pupils have gained sufficient proficiency in English to be able to benefit from instruction in it. In reality this is not so. Jones (1980) has suggested that pupils entering secondary school in Lesotho may actually know about 850 English words whereas English textbooks used in Lesotho's primary schools contain 2,000 words. Her study served to highlight a problem that had surfaced in many in-service workshops that were organised for mathematics and science teachers in Lesotho. Earlier, Towse (1977) had drawn attention to the crucial part played by language in the development of pupils' scientific understanding. The result was the organisation of two workshops (NUL, 1980 and 1981) at which participants were drawn from among mathematics, science and English teachers in Lesotho, Botswana and Swaziland. Apart from reports on the proceedings of the workshops, three resource books - English for Mathematics and Science, Language in Integrated Science, Language in Mathematics Lessons - have been produced.

Case-Study L5: Papua New Guinea. English is the medium throughout school education in Papua New Guinea. It is usually the third language of the pupil entering primary school, but may well be the fourth or even the fifth. Accordingly, problems of learning mathematics and science through ESL are thrown into particularly sharp relief. It is therefore appropriate that a considerable amount of research work is being undertaken (Jones, 1981a and 1981b; Meek and Feril, 1978).

An attempt has been made at first-year university level to try to alleviate persisting language difficulties. (Department of Language and Social Science, 1976). Self-study units of work developed by the Mathematics Department of the University of Technology have been carefully analysed, and language guides developed for them for student use. Both vocabulary and syntax issues are covered. It is suggested that similar work might profitably be undertaken in other countries, and at other levels of the education system.

Case-Study L6: Singapore. Singapore has four main languages: English, Malay, Chinese and Tamil. All four are used as media in primary education, with a trend towards an increasing use of English. A particularly interesting approach to the learning of primary science and mathematics through ESL was originally developed through the work of the Primary Pilot Project, 1970-75. Materials were produced for the English-medium schools, which take a very large proportion of children from homes in which English is not the main language. The strategy was to use science and mathematics as vehicles for teaching English, thus providing a more integrated approach to primary education than is usual. The team of curriculum writers included science, mathematics and English specialists. It is suggested that this approach to curriculum development could usefully be considered by other Commonwealth countries, particularly for the development of materials at the primary and lower secondary levels.

SECTION 3

Perceptual Difficulties: Introduction

Mastery of science and mathematics, and particularly of technical subjects, is highly dependent on the comprehension and manipulation of images. Some of these images are external to the learner, such as photographs, diagrams and graphs. Others are internal: the mental images that are formed as he studies a blueprint, a technical drawing, the drawing of a biological dissection, a diagram of chemical apparatus, or a geometrical figure.

All forms of external image have their own sets of conventions, an understanding of which is essential if they are to be interpreted correctly. These conventions have been developed for use in the corresponding fields of study, and most have their roots in technological societies. A student who has grown up in such a society and who has been used to seeing and learning from pictures, drawings and photographs since infancy usually develops an understanding of the relevant conventions without conscious effort. However, a student who has been brought up in a society where a particular form of imagery - for example, 'three-dimensional' diagrams - is not widely used may be baffled when he encounters it in the classroom. The situation is more serious when his progress in the subject concerned is dependent on his ability, not only to interpret the external image but also to manipulate the mental image that he derives from it as is frequently the case in many branches of science, technology and mathematics. It is small wonder that teachers from many member countries, particularly the less technologically advanced countries, identify perceptual issues as major learning problems.

In 1970, the Commonwealth Secretariat commissioned a review of research, undertaken up to that time in member countries on the difficulties that students in various cultural settings face in pictorial perception (Coppen, 1970). Since then further work including a recent review of the literature, accompanied by a test instrument, has been undertaken (Purcell, 1983a and 1983b). A lot of research has been done, some of which is reported in the case studies which follow. However, it has proved much harder to identify examples of teaching methods and materials that have been developed specifically to help to overcome the problems that the research has revealed. One of the problems facing those who seek to develop such teaching methods is the attitude, found among both teachers and learners, that an abstract, analytical way of thinking is 'better' than a visual mode of thought. Krutetskii distinguished between visual 'types' and analytic 'types' of learner. (Krutetskii, 1976, pp 313-329). The fact that Einstein said that he rarely thought in either words or in mathematical symbolism, but almost always in visual imagery, indicates that the analytical thinker is not necessarily more intellectually able than the visual thinker! There is a danger in the concrete - iconic - symbolic model of intellectual development. Much school education, even when based on this model, tries to hurry the learner through the 'stages', with an abstract analytical mode of thought being the goal. A better model is to regard progression to the next stage as adding a new mode of thought to the learner's existing intellectual skills.

'Perceptual', 'visual', 'spatial' are all adjectives used to describe the range of abilities under consideration in this section of the paper. These abilities are of various kinds, as may be seen (!) by considering what a student needs to be able to

do in order to deal successfully with an assignment in a science, mathematics or technology textbook. He must be able to:

- (a) read and understand the words used;
- (b) 'read' and understand any diagrams, graphs, photographs or tables;
- (c) imagine the situation being described;
- (d) imagine what changes, if any, take place in that situation;
- (e) represent the situation on paper, sometimes in diagrammatic form, sometimes in symbols, and sometimes in words.

Only then can he set about the task itself. Note that these requirements come in three stages: (a) and (b) concern understanding information presented to him, (c) and (d) require him to construct and operate upon a mental image, and (e) demands an ability to use the appropriate representational conventions (whether of words, symbols or diagrams) himself. It is worth analysing further the range of difficulties that may face a student, using these three stages.

Understanding information presented to him involves:

- (a) observation, comparison and matching of visual details. There is evidence from a number of countries that inexperienced students tend to focus on a single detail, and to interpret the whole diagram from it.
- (b) understanding photographs. Studies in some societies show that black and white photographs are much better understood than colour photographs; elsewhere the reverse is the case.
- (c) understanding pictorial conventions. This has many aspects: symbolism, perspective, dimensionality, foreshortening, abstraction, time-sequence in a series of diagrams, contour-maps, a system of scale and its depiction.

The source documents referred to in the case studies that follow contain examples of each of these aspects.

- (a) forming an image of a three-dimensional object from a two-dimensional representation of it. Without this skill, a student will make little progress in many branches of mathematics and technical education.

- (b) transforming a mental image. Can the student move his image around? Enlarge it? Invert it? Change its shape? 'See' it as someone with a different viewpoint would see it? These are not skills that are inborn, or that just 'happen'; they result from need and from practice, and can be reinforced by specific teaching.
- (c) visual memory. How long do images survive? There is evidence that long and stable visual memory (particularly of two-dimensional images) is a highly developed attribute of many pre-technological societies. Exposure to technology, and more particularly the experience of western-type school education, diminishes this ability.

Using representational conventions involves:

- (a) copying two-dimensional images. This may be drawing, or copying graphs or diagrams or a tile pattern. Students who have not had experience of such activities in childhood do not find even such relatively straightforward tasks easy.
- (b) drawing three-dimensional diagrams. This is an aspect where explicit teaching of the appropriate conventions is necessary, for example 'verticals go directly up the page', parallels remain parallel', or the conventions appropriate to the type of drawing (isometric, perspective, etc.) required. There is evidence that teaching students to draw diagrams correctly also increases their ability to interpret diagrams presented to them. It is important to realise that these skills are different from those of the artist; the conventions used in diagrams in science, technology and mathematics are not 'what one sees'.
- (c) drawing maps. This is listed as a separate skill, for two reasons: it has its own complex set of conventions, and it is a representation from a viewpoint at which the student is unlikely ever to be in reality. The skills of drawing and reading maps appear to overlap with those needed in work with plans in, for example, architecture and technical drawing. It is noteworthy that geography teachers devote a considerable amount of time specifically to teaching skills of map-reading.

There are, of course, no clear boundaries between the abilities listed in the foregoing analysis. 'Spatial ability' is a complex set of interlocking skills, and training in one aspect is likely also to improve others. There is a strong link with language. Languages differ markedly in the richness of their

spatial vocabulary, and it appears that there is correlation between the general level of spatial ability in a society and the level of sophistication of its spatial vocabulary.

The spatial abilities of a student who is studying science or a technical subject through ESL may still be constrained by the concepts implicit in his mother tongue. For example, it is hardly surprising that a pupil in Ghana confuses a sphere with a circle, when his mother tongue uses the same word for both - and particularly when his mathematics textbook draws them both as O. Many languages of the Commonwealth use the same word for above/surface/, slope/steep/hill, wide/flat, picture/shadow, down/under, side/edge, long/tall, and so on. In some, there are no words equivalent to round, slope, surface, regular, irregular, line, shape, direction, horizontal, vertical, corner, second, diameter, diagonal, and so on. It seems safe to assume that a pupil from such a language group will not have had opportunity to think about these concepts in childhood, and hence is meeting them for the first time in school.

It is now widely recognised that there is a close link between a child's spatial ability and his social and physical environment (Wilson, 1981, pp. 136-144). 'Spatial ability', however, is too broad a term, as has already been pointed out. Particular spatial skills characterise particular groups of people; see, for example, the case-studies on Canada and the South Pacific following. Another illustration comes from Australia, whose Aborigines have a sense of position and direction which is far in excess of the corresponding abilities of white Australians. 'An Aborigine is never lost' (Harris, 1980, p.11). Even after a long and circuitous chase in a flat, featureless scrub-covered environment, the Aborigine hunter has an unerring knowledge of his position relative to his starting-point. Such an ability implies the use of a 'mental map' which is continually up-dated and realigned with a mastery that astonishes non-Aborigines (Lewis, 1976, p.262). Yet, in schools, Aborigine pupils generally perform very poorly, even at geometry. Why is this? The superficial explanation, 'lack of spatial ability', is clearly absurd. Disregarding questions of motivation, the problem seems to be one of developing teaching methods and materials that start from and build on, the pupils' known skills, rather than expecting them to adapt to a standard school course that uses method, books and conventions which were originally developed within a very different cultural environment. Work along these lines is progressing, particularly in the Northern Territory of Australia.

Case-Study P1: Canada. Canada provides a unique setting within the Commonwealth to investigate the relationship between the physical environment and spatial abilities. Much of its land area is flat and permanently snow-covered, and various studies have been undertaken among its Eskimo citizens to study this relationship. Details are contained in, inter alia, Berry (1966,

1971), Berry and Annis (1974), Dasen (1975), Kleinfield (1973), MacArthur (1967, 1973, 1975) and Vernon (1966). The conclusion of all these studies is that Eskimos have a high level of spatial ability. This is independent of their level of literacy; indeed, it has been observed that they often perform relatively poorly in verbal tasks, whether oral or written. Nor do there appear to be differences between the sexes in spatial abilities, a finding which contrasts with that for most other groups of Commonwealth citizens, including white Canadians.

Case-Study P2: Jamaica. A series of studies has been undertaken among both primary and secondary school pupils in Kingston, to assess their levels of spatial and 3D drawing abilities and to propose ways of reinforcing them (Mitchelmore 1973, 1975, 1976, 1980). Among the conclusions are the following:

- (a) Pupils found considerable difficulty in drawing accurate representations of simple three-dimensional objects and in reproducing two-dimensional patterns.
- (b) The difficulties experienced by boys were less acute than those experienced by girls (this contrasts with the fact that schoolgirls out-perform school-boys in Jamaica in almost all school subjects, including in some cases science and mathematics).
- (c) Many of the difficulties could be traced back to the primary school mathematics curriculum, which is strongly oriented to arithmetic and provides little opportunity for spatial work.
- (d) The problems can be alleviated by the use of manipulative materials in primary school mathematics, by a greater use of diagrams at all school levels, and by a more informal approach to the teaching of geometry.
- (e) The pupils' social environment does not appear to lend much support to the development of the kind of spatial skills necessary for work in science, mathematics and technology. For example, newspapers in Jamaica contain plenty of photographs, but very little use is made of any form of graph or diagram in presenting information.

Case-Study P3: Kenya. In Kenya, attempts to assess the effectiveness of diagrams used in posters in rural health education programmes gave rise to research which yielded results of relevance to schools. The research (Holmes, 1966; Shaw, 1969) attempted to analyse the factors which tend to favour or to impede the recognition of drawings of familiar things. The subjects of the research covered a wide cross-section of age and level of formal education. In the first part of the work, diagrams of familiar objects were presented, and respondents asked what they thought they were.

In the second stage, those objects which had been misidentified most frequently were redrawn in a natural setting alongside two or three other objects related in everyday life to test whether such a setting would aid recognition. The third stage of the research consisted of comparing the recognition levels for pairs of diagrams, each of the same object but using different drawing conventions.

Among the major conclusions of the study, the following are relevant to schools:

- (a) Many respondents did not look at even a simple diagram as a whole, but focused on a single feature and based the whole interpretation on that.
- (b) The idea of a drawing as representing a type, or class, was often absent.
- (c) "Cartoon stick" characters, and isotype symbols, caused little difficulty.
- (d) Placing an object in a natural context does not necessarily increase recognition.
- (e) Pictorial symbols which can have a literal interpretation or can be given an extended meaning (e.g. the skull and crossbones motif, widely used in Kenya on poison bottles and on electricity poles) are often only interpreted literally.
- (f) Excessive detail, and excessive deletion of detail, both seriously reduce the comprehensibility of a drawing.
- (g) Where an understanding of the conventions of perspective is important to comprehension of a picture, correct interpretation is made more difficult.
- (h) When a familiar object is drawn larger than reality, it is less often interpreted correctly than when drawn life-size or smaller.

Case-Study P4: Nigeria. An example of collaboration between two Commonwealth member countries to study a specific educational problem in depth was a joint University of East Anglia/University of Lagos research project concerned with the ability of Nigerian secondary school pupils to perceive correctly depth in chemical diagrams. Much of the work centred on diagrams and photographs of frameworks of the kind commonly found in chemistry textbooks to model molecular structures. It was shown that foreshortening and relative size cues caused difficulties, whereas superimposition and elevation cues were generally helpful to students. A remedial self-instructional teaching programme

was developed to increase students' ability to interpret correctly three-dimensional chemistry diagrams. (Alonge, 1977; Evans, 1974; Evans and Seddon, 1978; Nicholson, 1974, 1976; Nicholson and Seddon, 1977a, 1977b; Nicholson, Seddon and Worsnop, 1977; Ross, 1977; and Worsnot, 1975).

Case-Study P5: Papua New Guinea. Probably more work has been done on perceptual difficulties in Papua New Guinea than in any other of the smaller Commonwealth countries. Most of this work has been centred on the Mathematics Education Centre at the University of Technology, Lae. It is published in Ausburn and Ausburn (1981, 1982), Bishop (1977, 1978), Bishop and Tombs (1982), Clarkson (1981, 1982) Lean (1980) and Lean and Clements (1980). Although having primary reference to the relationship of perception and imagery to the learning of mathematics, the findings and recommendations would seem to be easily transferable to science and technical subjects. They include:

- (a) Many students from rural backgrounds have a highly developed visual memory.
- (b) Traditional methods of teaching mathematics do not build on this, but are strongly oriented to symbolism rather than diagrammatic representation.
- (c) There is little correlation between different perceptual abilities. For example, the ability to construct and operate on three-dimensional mental images does not necessarily accompany good two-dimensional visual memory.
- (d) Spatial abilities can be taught.

The work in Papua New Guinea includes some attempts to develop teaching methods that will develop students' spatial abilities. More, however, needs to be done to translate the considerable body of research findings into teaching methods and materials. In this respect, the work contrasts with that in the culturally-related Solomon Islands. There, even though very little research has been undertaken, suitable mathematics teaching materials are being developed which in their presentation and style, and in the classroom methods that they imply, draw heavily on the pupils' indigenous culture to develop geometrical and more general spatial ideas within the framework of a broad mathematics curriculum.

Case-Study P6: South Pacific. The University of the South Pacific (USP) serves eleven Commonwealth island countries. Some of these are coral, and basically flat. Others are of volcanic origin, and are mountainous. In the smaller and more scattered island groups, travel by canoe demands navigational skills of a high order. It has been reported from USP that in their academic studies students from the coral islands tend to

have greater difficulties with three-dimensional visualisation than students from the volcanic islands. On the other hand, those from the small islands often have a very highly developed sense of direction and relations in two-dimensional space. Such observations act as a reminder that the development of perceptual skills is embedded in the individual's total social, environmental and cultural context. They underline the importance of careful analysis of this context, and of a deliberate attempt to provide, in the early years of primary education, experiences and activities that are designed to develop those spatial skills that do not receive much support from the child's environment.

SECTION 4

So what should we do?

Be based on the information from member countries, a number of proposals are made below for action designed to tackle the linguistic and perceptual problems that have been discussed. It is unlikely that all these proposals will be relevant to any one country; it is very unlikely that none of them will.

1. Language difficulties: proposals

(a) In all countries where a significant number of children learn through ESL steps should be taken, particularly in initial training, to increase teachers' awareness of the complexity and nature of language issues in the classroom.

Comment. While this is particularly in situations where the teacher does not speak the pupil's mother tongue, it is also important where teacher and pupil share the same first language. Many teachers, having become fluent in English, appear to forget their early misunderstandings and struggles to learn through the medium of ESL.

(b) At primary level, the classroom atmosphere should be one in which the children feel free to use their first language, if they wish to, in discussing their learning with each other and where appropriate with their teacher.

Comment. Pressure against the use of L1 can be not only psychologically damaging to young children, but can inhibit their learning.

(c) Every effort should be made to develop a child's oral and written fluency in his first language, even when English is the medium of education.

Comment. Recent research findings revealed that, for children of comparable fluency in English, the degree of mastery of L1 is a major determinant of their ability to reason effectively

in English. This suggests that L1 needs to be given a high social status. Also, parents may need to be oriented to value their own language.

(d) Studies should be undertaken, language by language, to see where their scientific, mathematical and technological registers are not congruent to those of English.

Comment. The work quoted in the Lesotho case-study, L3, is an excellent example of where this is being done. Work which has been going on for many years in Tanzania and in Malaysia, in Kiswaheli and Bahasa respectively, may also have lessons for other member countries where ESL is the medium at school level.

(e) The scientific, mathematical and technological registers of English must be taught explicitly, in context, in ESL situations.

Comment. In particular, great care must be taken to teach the precise meanings and use of logical connectives. As most of them are little words, it is only too easy for the teacher to assume that they are understood. In fact, it is much easier to teach an ESL pupil the meaning of 'thermometer' or of 'distillation' than it is of 'if' or 'some'.

(f) Children should be encouraged to verbalise their activities and their learning.

Comment. In much of education, writing has been accorded greater esteem than speaking. This is particularly inhibiting in an ESL context. If pupils are encouraged to talk about what they are doing in science, mathematics and technology, it will not only increase their competence and confidence in the accurate use of language and enhance their learning, but it will also reveal sources of difficulty and misunderstanding. In the early years of ESL medium, such talking should not necessarily have to be in English.

(g) More emphasis should be placed on concrete activity, and on spatial or visual work, in the study of science, mathematics and technology at all school levels.

Comment. This reinforces proposals in paragraphs 2f and 2g following.

(h) Every mathematics, science and technology development team in an ESL situation should include an English language specialist.

Comment. Case-study L6 illustrates.

2. Perceptual difficulties: proposals

(a) In those countries where it is not already being done, a research programme should be undertaken to identify the specific perceptual strengths and weaknesses of pupils from different cultural backgrounds.

Comment. Such research need not be elaborate. The references in the case-studies provide guidance on what methods are likely to prove fruitful. It is not enough to rely on classroom anecdote, "the pupils cannot draw 3D diagrams properly"; it is necessary to find out much more precisely what skills they possess and where their weaknesses are, which result in their not being able to do it. If their strengths and weaknesses can be related to their cultural and physical environment, so much the better.

(b) Teaching programmes should be developed to alleviate the specific perceptual difficulties pin-pointed by research.

Comment. Perceptual skills can be taught. All forms of diagrammatic representation have their own conventions, and these must be learned both for correct interpretation and for use by the pupil. Just as learning the conventions of writing improves a child's ability to read, so learning to use diagrammatic conventions helps to improve his interpretative skills. Ideally, drawing and 'reading' of diagrams, including graphs, should be taught concurrently in schools. Specific ideas for teaching activities of the kind envisaged are contained in Ausburn and Ausburn (1982), Bishop (1977), and in the references cited in the Nigeria case-study P4.

(c) Various types of pictorial representation should be used as much as possible in learning materials for science, mathematics and technical subjects.

Comment. Lack of particular perceptual skills often result from a previous lack of the need for them. It is therefore important that different forms of pictorial representation are used in materials at primary level. There is some evidence (Clarkson, 1981) that diagrams may not have the desired effect unless they are an integral part of the information being presented.

(d) While it is important to include different types of pictorial representation in classroom materials, the particular style of, for example, drawings used should be one with which the pupil is familiar from his out-of-school background.

Comment. This is an application of the principle 'build on strength'.

(e) Teaching methods should capitalise on pupils' strengths.

Comment. For example, in societies within which visual memory is highly developed, it is advisable to present, wherever possible, material that must be remembered in a visual, rather than in a symbolic or verbal, form.

(f) Greater use should be made of manipulative activities with concrete apparatus and aids at primary school level.

Comment. Familiarity with, and repeated handling of, relatively simple shapes such as cubes and spheres is likely to improve pupils' spatial abilities significantly. (Bishop, 1973; Micheltore, 1976). Bishop (1978) points out that the effect is likely to be greater within a society which offers only limited support to the development of spatial skills. While the primary and lower secondary school years are the ideal stages to use plenty of concrete aids, Saunderson (1973) has shown that they can still be effective in strengthening spatial abilities even among student teachers.

(g) There should be deliberate emphasis on visual aspects in constructing school mathematics curricula.

Comment. Most school mathematics curricula are designed to wean pupils away from dependence on diagrams towards a symbolic, analytic, algorithmic style of working. This wastes the opportunity that mathematics provides for developing pupils' spatial abilities for use both within mathematics and in science and technical studies. More use should be made of diagrams to represent and summarise mathematical ideas; practical activities associated with the study of area and volume should be increased; plane and solid figures should be constructed; and activities associated with the locus of a moving point devised (Lean, 1982).

(h) The teaching of school geometry should have as its major objective the development of a feeling for space and spatial relationships, rather than the development of abstract deductive thought.

Comment. Dieudonne, in New thinking in Mathematics (OEEC, 1961) said it all: "Euclid must go! It is one of the main tasks of secondary schools to train and develop the intuition of space in students, and at the same time to place it in the logical frame which will enable them to use it later. Nothing should be spared to reach that goal as soon and as completely as possible." An attempt to develop the teaching of geometry along such lines is provided, for example, in the DIME Project in Scotland (Giles, 1982).

(i) Pupils' spatial abilities will be assisted by relating the teaching of mathematics, and particularly geometry, to art and technology.

Comment. Bishop and Tombs (1982) describe a good example.

(j) The spatial registers of pupils' mother tongues should be analysed, to indicate where difficulties may have linguistic as well as conceptual origins.

Comment. This is an important and complex field in which little work yet appears to have been done in member countries. Olson (1975) provides a relevant reference from outside the Commonwealth.

(k) Work on perceptual difficulties should be included in the initial training of science, mathematics and technical teachers.

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CHAPTER 2: INTERRELATED TEACHING OF SCIENCE, MATHEMATICS AND
TECHNICAL/VOCATIONAL SUBJECTS AS A PREPARATION FOR
THE WORLD OF WORK
J. Bigala and K. King*

Introduction

There are two basic issues to be raised when considering the links between school and the world of work. First, can the curricula at school level be more sharply focused to prepare students for the world of work? How can the right balance be achieved between academic subjects and the development of relevant skills? Secondly, is there adequate understanding and co-operation among those responsible for academic and vocational subjects? Are there positive measures that can be taken to make this relationship and understanding more effective in terms of the development and education of youth and adults?

A consideration of education for the world of work will, therefore, include a number of aspects. First, the acquisition of skills and knowledge relevant to the needs of the society; secondly, motivation to learn; thirdly, the development of character, values and ethics in order to learn how to live and work together in society; and fourthly the development of judgement and wisdom, attributes that may be acquired through experience and example.

Lack of co-operation between education and the world of work is a matter of deep concern to those involved in the development of young people.

There is considerable room for experimentation, but many government planners, educators, and parents are naturally cautious about new methods to link education and work. There is an understandable fear that the needs of modern work processes are sometimes narrowly prescribed and are therefore detrimental to the long-term interests of the learner, employer, and his society. However, science, mathematics, technical and vocational education must be associated with the world of work and the interaction between these subjects and employment should provide a mechanism for curriculum innovation and renewal.

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Matching Curricula to the World of Work

Two major problems face educators who wish to establish innovations in curricula to link science, mathematics, technical and vocational education with the world of work. First, to decide the most appropriate level in the school curriculum for the introduction of the innovative material, bearing in mind that the number of years spent in formal education could vary for different pupils. Secondly, to determine the impact of innovative curricula on accepted cultural values.

The design of curricula that interrelates the teaching of science, mathematics, technical and vocational subjects with the needs of work should be based on in-depth assessments of national technological development needs. This assessment will enable curriculum designers to set broad objectives which will endure in the post-school period. In the design of innovative curricula close attention should be given to environmental and cultural dimensions - for example, how can we deal with pollution and desertification?

Models of Interrelated Curricula

For a long time science has suffered from an identity problem because the subject area is divided into several separate disciplines, and although there are common topics - particularly in physics and chemistry - the teaching of each subject is generally confined within well-defined theoretical boundaries. Individual science subjects are often taught in a way that puts undue emphasis on factual knowledge, rather than the solution of problems through the practical application of science and technology. In everyday life the boundaries between science and technology merge and overlap and the artificial divisions between subjects in school curricula disappear. If the applications of science and technology are to have a real meaning to boys and girls in the world of work their educational experience in these subjects should be based on an interrelated curricula approach. The following models illustrate two possible ways to interrelate the separate subjects that make up the broad areas of mathematics, science, technical and vocational education.

MODEL I.

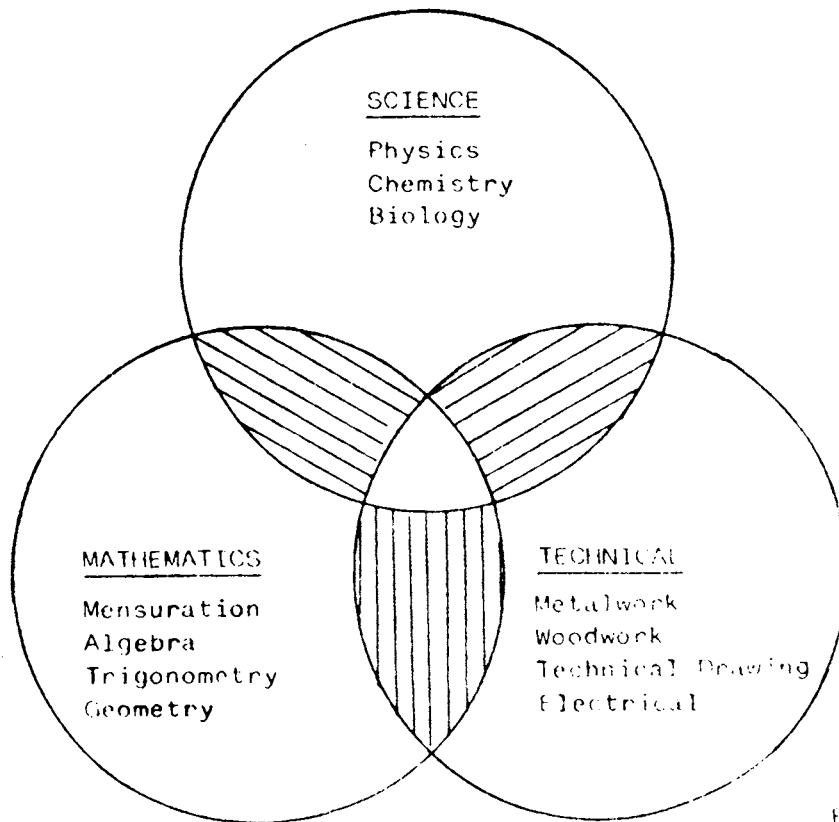


FIG.1

In this model the three curriculum areas of science, mathematics, technical and vocational education maintain their separate identity but overlap, as shown in Fig.1. The area of overlap between two subject areas contains topics of a common interest - for example the overlap sector between mathematics and technical areas could contain applications of trigonometrical functions applicable to both subjects. In the overlap sector between science and mathematics the use of graphical solutions to problems in physics is an obvious interrelated topic.

In the sector where all the subjects areas overlap the interrelated topics are likely to have a direct relation to applications of science and technology in the world of work. Topics such as the transfer of heat could be treated so as to draw on scientific laws, the use of mathematics to derive formula, and the practical applications of heat transfer in, say, motor vehicle technology. Other topics in this sector could include the relationship between energy and power - using teaching methods that link science, mathematics, and technology elements of energy transfer and power transmission.

The design of curricula in this model could include the use of project work in the interrelated sectors. Such project work, based on a problem-solving approach, would draw on a wide range of subject matter from more than one main area of study. Furthermore, project work of this nature could be designed around practical applications of science, mathematics and technology in the world of work - for example, the use of portable forms of electrical energy, effects of an electric current, and the care and maintenance of electrical appliances.

One of the advantages of interrelating curricula in this manner is that the degree of interrelation (extent of overlap) can increase in gradual steps, commensurate with the availability of educational resources. Thus, in the early stages of a change from separate to interrelated curricula, the sectors of overlap may be small, and confined to those topics that can be immediately identified as common elements in more than one subject area. Such an approach would also allay fears among subject specialists that the separate identity of their discipline was being threatened by a wholesale curriculum renewal. A second advantage in this gradual approach would be that topics in the central sector - where all subject areas merge - could be examined in detail in order to identify relationships between school curricula and the world of work.

MODEL II

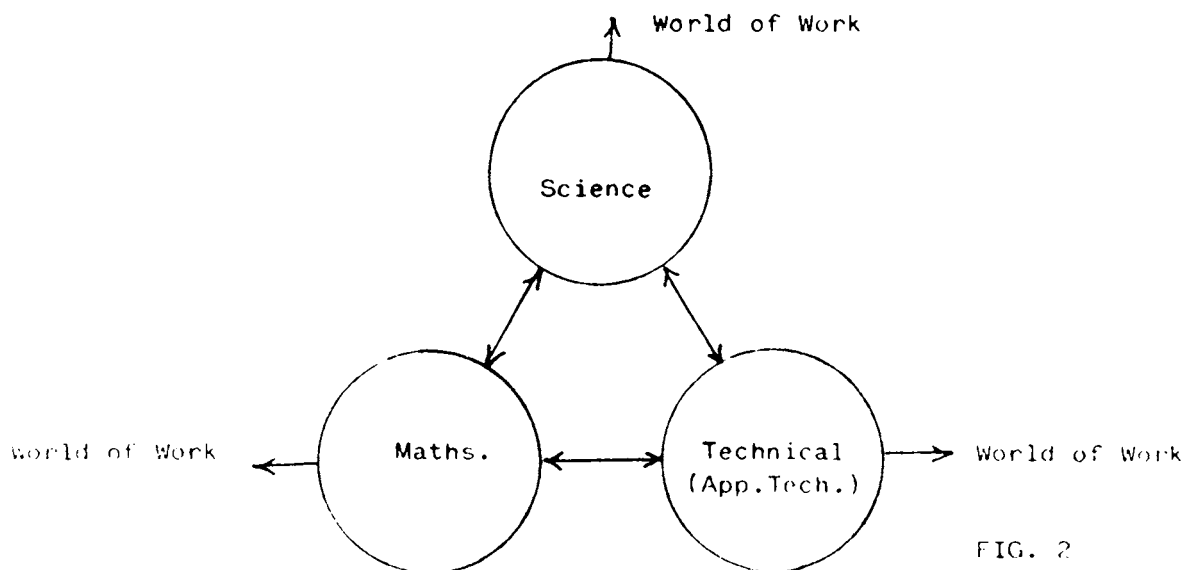


FIG. 2

In this model the three curriculum areas - science, mathematics, technical and vocational education - maintain a separate identity, but in each case the curriculum is directly related to the world of work. This method would enable teachers to introduce topics in each curriculum area to provide appropriate skills and knowledge for employment, for example mathematics for self-employment, and science for rural and urban development. The third curriculum area - applied technology - would be designed to complement the other two areas and also to complete the interrelation of all subjects. Although this curriculum model does not offer the close interrelation of subject matter as in Model 1, it does provide an opportunity for curriculum designers and teachers to focus specific topics in the curriculum on work experience. By careful management of the total curricula it should be possible to draw on the threads of these relationships between the main areas of curricula and the world of work in order to reinforce interrelation. For example, the relationships between calculations on fuel costs (mathematics), conservation of energy (science), and the design of heating appliances (technology) could be interwoven so as to provide a comprehensive understanding of efficiency in the utilisation of fuel.

In both of the models described there are four essential common factors to consider:

- (a) The various subject disciplines are interdependent.
- (b) Knowledge and skills which are common to several subjects will be used in practical work.
- (c) The interrelation of science, mathematics, technical and vocational curricula must be balanced with other school curricula.
- (d) The interrelation of curricula should provide the kind of experience that enriches the development of pupils, and encourages creativity and imagination.

Implementation of Interrelated Curricula

In order to effect a smooth transition from traditional curricula to an interrelated approach to the teaching of science, mathematics, technical and vocational education it is advisable to set out guidelines for action, based on a number of important issues.

- (a) Interrelated curricula, covering science, mathematics, technical and vocational education, should not be developed in isolation from other school curricula. There is a need to review the whole curricula in a school so that the design of interrelated curricula for science and technology subjects is balanced between the needs of employment and a need for close matching with other important school subjects. Curriculum development and implementation should therefore involve all teaching staff. A failure to involve all staff in the transition process could isolate science and technology subjects from the educational objectives and goals of a school.
- (b) Adoption of interrelated curricula will cause new demands for educational material and equipment. Such demands must be carefully considered in the light of available resources at the design stage in the development of interrelated curricula.
- (c) Because cooperation between staff, and close coordination of teaching programmes are essential requirements for the successful implementation of interrelated curricula it may be useful to set up teacher working groups to organise the transition process.
- (d) Whenever possible the interrelated curricula should use practical problem-solving methods - involving the use of materials to develop cognitive and manipulative skills. Such methods will allow the translation of ideas into practical realities by:
 - (i) identifying a problem,
 - (ii) selecting an appropriate solution,
 - (iii) implementing practical outcomes,
 - (iv) developing an awareness of the inter-relationship with other subjects in the school curriculum.
- (e) Every effort should be made to phase in topics in one subject so that they assist learning in other subjects. For example, mathematical processes should be introduced at an appropriate time to match the needs of work in the science and technology curricula. In this way pupils are made aware that subjects are not taught in the isolation of separate disciplines, but are part of a total curriculum.

- (f) The traditional divisions between arts and science could be removed by the implementation of inter-related curricula. Many of the topics in science and technology have a direct relation with arts subjects, for example the use of technical drawing techniques in artwork, and technical report writing as an English language exercise.
- (g) The implementation of interrelated curricula will make new demands on teaching skills. The use of innovative teaching methods - an essential feature of interrelated curricula - will require teachers to modify their traditional attitudes and role. In-service training organised at local and national levels will be required to develop new teaching techniques and to foster positive attitudes among teachers and administrators.
- (h) Pupils and parents should be encouraged to take a positive view over the introduction of interrelated curricula. Pupils must be actively involved in practical activities connected with preparations to implement the new curricula, and meetings between parents and teachers should be organised to discuss the implications of curriculum change. In addition, the cooperation of the parents should be sought in efforts to relate curriculum to the world of work. Some parents may have the kind of work experience relevant to particular topics in the interrelated curriculum, and their interest and help could be useful to teachers.
- (i) Industry and commerce, in the public and private sectors, should play an active part in the implementation of interrelated curricula. Work-study programmes, drawn up by school and employers, could reinforce the teaching of science and technology and also provide a bridge between school and the world of work. Such on-the-job teaching experience involves pupils in real work situations and conditions and offers an opportunity to understand adult roles and responsibilities.

The implementation of interrelated curricula for science, mathematics, technical and vocational education that interacts with the world of work provides a new and exciting challenge to teachers, pupils, parents and employers. Interaction of curricula demands interaction of effort on the part of all those who wish to ensure that young people are given the best possible educational preparation for the world of work - a world of constant change and increasing complexity.

CHAPTER 3: TEACHING SCIENCE, MATHEMATICS, TECHNICAL AND VOCATIONAL SUBJECTS IN AN INTERRELATED WAY
A C Bajpai*

Introduction

In many schools the curriculum is based on a timetable of separate subjects serviced by specialist teachers who work in isolation from teachers in other subject areas. Also, subjects are offered as an academic discipline with little or no reference to their practical value. In these situations the teaching of science and technology-based subjects is largely confined to the classroom and the importance of doing, making and organising is often neglected.

In order to break down the rigid lines of demarcation between subject disciplines the interrelationship between subjects must be recognised and exploited so that science and technology education is treated in a comprehensive way. The need to interrelate science, mathematics, technical and vocational curricula is clearly seen by an examination of technological developments in the world of work. For example, the scientific research laboratory in chemical-based industries uses modern technology as a basis for measurement and the interrelationship between mathematics, physics, biology and chemistry is fundamental and undeniably strong, especially in respect of one simple mathematical concept, namely ratio and proportion.

It seems natural, therefore, to relate science, mathematics, technical and vocational subjects so that rigid boundaries are crossed in a smooth and effective way. Such interrelation will provide an education with interest and purpose, and assist the process of incorporating new technologies into teaching programmes. In order to reap the maximum benefit from an interrelated approach to the teaching of science and technology subjects, two essential requirements must be met - the cooperation of teachers and the provision of comprehensive teaching modules.

An interrelated approach to the teaching of science and technology subjects is likely to stimulate a greater motivation to study. Many pupils find that the isolated nature of school curriculum subjects - with little reference to experience related to the world of work - is totally irrelevant to their perceived needs. Dissatisfaction with traditional academic curricula may be one of the underlying causes of behavioural problems that arise in the final years of formal schooling.

*With assistance from research students Messrs. Stanley Turner and Rodney Bond

It must be recognised that any change from traditional curricula to a more interrelated approach is likely to be opposed by some teachers who may have serious misgivings about such curriculum reforms. However, if teachers are fully involved in every stage of change they are likely to modify their attitudes and agree that the successful development and implementation of interrelated curricula must depend on a new teaching approach - with a greater emphasis on guidance for teachers. The preparation of curriculum materials, guidelines on implementation, management and assessment are also activities that require the participation of teachers and their whole-hearted support. Other areas of co-operation between teachers and education authorities are concerned with pre-service and in-service training, their implementation of interrelated curricula, and the provision of resources including buildings and equipment.

The interrelation of science, mathematics, technical and vocational curricula is likely to follow two separate, but related development paths:

- (a) The interrelation of existing curricula following identification of related topics.
- (b) The design of teaching modules covering topics commonly used in all science and technology subjects.

Resource constraints and a need to proceed in a step-by-step manner may favour the adoption of (a). However, in the long-term the development of interrelated curricula will lead to the production of special modules as described in (b). One topic, of essential use in all science and technology subjects, is measurement. Even at pre-school level measurement is important in respect of counting, classification and recognition. In later stages of education, measurement is the all-pervading topic in every aspect of science and technology education. The purpose of this paper is to develop a teaching module on measurement, together with guidelines on ways to present it as an interrelated topic with a view to helping communication in science, mathematics and technology.

A further purpose of this paper is to provide a basis for discussion amongst groups of teachers, educationalists and parents so as to help the learner to understand the reason for studying a variety of school subjects. It is hoped that the ideas in this paper will provide some enrichment in the curriculum thus opening new lines of communication between the teachers themselves, provide cross-fertilisation amongst subjects and thus increasing communication between teachers and students as well as between students. In addition, the links between the students and the society in which they are living and in which they are hoping to make a contribution will be further strengthened.

Measurement in Science and Technology

In all science and technology subjects the measurement of physical properties is an essential objective, or a necessary component of an objective.

Physics and Chemistry are taught as a set of principles and practical phenomena, the latter being quantified by fundamental measures (count, time, length and mass) or as derivations, for example:

- specific heat from volume (length), mass and temperature
- modulus of elasticity from mass and length
- melting point directly from temperature
- co-efficient of thermal expansion (length), area or volume) all in terms of length and time
- electric charge from mass and time in a chemical cell
- molecular weight from atomic weight and a count of atoms
- density from mass and volume (length)

Biology takes account of the fundamental cell structure of animal and human forms, the macro-components of which have identifiable properties and specific structures which relate to particular species. The following examples illustrate some ways in which measurement occurs within biology:

- counting is used to establish and verify laws of genetics
- time is used to measure (with counting) pulse rate and heart beats
- cells are identified by colour and shape as determined by the configuration of lengths and angles
- cell multiplication is determined by counting and measured against temperature
- count of macro-components, eg. number of ribs, vertebrae, etc.

Technical Education supports the fundamental industrial processes, namely design and manufacture. Measurement takes place at all stages varying from the use of elementary instruments to automatic, continuous monitoring devices. Examples of measurement are as follows:

- counting and classification
- shape, angle and size are measured with geometrical instruments
- smoothness is measured by the abrasiveness of filing and sanding devices
- automated machine tools can be programmed to produce a finished product having predetermined measures
- temperature is measured continuously and automatically regulated in order to maintain a constant temperature in the heat treatment process
- hardness of metals is measured on a variety of scales

Mathematical education is concerned with the training of clerical, operative, retail and wholesale distributive trades. Formal education is usually available eg. in the office skills. Examples of measurement are:

- shorthand/typewriting speed; teaching tabulations to typists
- money calculations as taught to clerks, cashiers, hotel receptionists, etc.
- reading electricity supply meters
- making clothes and other items in small businesses/cottage industries
- weighing of raw materials by process workers
- measuring of customers in shoe and clothes shops to obtain appropriate sizes
- measurement involved in buying some improvement materials, e.g. timber, screws and various fittings

Teaching Measurement - An Interrelated Approach

In order to present the topic of measurement in an interrelated way it is necessary to establish a number of objectives and identify supporting strategies.

To assemble a team of specialists from a teaching establishment who are sufficiently interested and motivated to co-operate in the use of interrelated curricula

Strategy: Identification of a co-ordinator who has specialist knowledge and teaching experience in one or more of the related areas. There must be a full acceptance of the new subject INTERRELATED STUDIES within the establishment. This would not mean that specialist subjects would no longer exist in the timetable any more than one would expect, for example, that mathematics, science, English and other topics would not exist for students studying A-level general studies in the United Kingdom.

To motivate the students to learn.

Strategy: Use of colourful, attractive and well-prepared materials which relate to the real-life experiences of students. The co-operation of local commercial and industrial organisations must be sought - it is the experience of the author that a considerable amount of support is usually available.

The prepared material should take into account teaching strategies, programme planning, laboratory management and assessment. Teachers need help in these strategies right at the start so that they can develop new curricula.

To ensure that teachers are sufficiently prepared to cope with an interrelated approach, by means of an available teacher/pupil module and separate pupil modules.

Strategy: Preparation of separate teacher and student modules. The teacher module, while containing the student's material will be much more comprehensive in respect of background information, and the use and variation of this material will be at the discretion of the teacher. Solutions, hints, etc., for student exercises will also be provided. The format of the teacher module will clearly show the separation of teacher and pupil material. The teacher/user must understand that the content of the module will require regular updating by the teacher.

To draw on the experiences and particular interests of students.

Strategy: Teachers and students will need to bring together skills, experiences, knowledge, understanding, imagination and judgement in order to solve a problem. The teaching of these will be a difficult task but it is hoped that students will learn through experience and practice under supervision by the teacher.

Students' experiences, though sometimes not first-hand, are always relevant, e.g., space travel through television broadcasts. It is important to give guidance on the collation and recording of experiences and interest material. An example is that of newspapers, being particularly useful as they regularly report on developments in commerce, industry and technology.

To ensure that the treatment of important phenomena is at a level of explanation suited to the students.

Strategy: Demonstrations will help to show the results of theoretically derived relationships. Actual experiments carried out by the students should be encouraged for them to understand the explanations of the phenomena under investigation. Where results are to be expressed graphically, a linear graph should be used and, where appropriate, a logscaled graph (detailed explanation of logarithms may be left until a later stage).

To consolidate learning processes by suitable student exercises.

Strategy: The exercises should be requested as the response to key questions and in simplest form this could imply a descriptive essay. At the other end of the scale problems requiring numerically calculated answers should be applicable to real-life situations, whenever possible. Practical and investigative assignments would need to be carefully structured and checked for continuity with particular attention paid to the time for completion by the average student. Where there are weaknesses in pedagogic, arithmetical and algebraic processes, suitable practice exercises (with self-checking facilities if possible) must be available. Using these strategies teachers should guide students towards independence in their learning as a preparation for the world of work.

To produce modules which are sufficiently flexible for a variety of teaching methods to be employed.

Strategy: There must be regular discussions between members of the teaching team to promote a greater use of audio-visual aids. If such aids are in short supply, e.g. micro-computers, it is acceptable to have a single piece of apparatus for use with a class. As an extreme example of the non-availability of apparatus for student use, the teaching of atomic energy generation has to depend entirely on slides, films, models and diagrams.

Sample Modules on Measurement

In order to demonstrate how the teaching of measurement in an interrelated way can be carried out according to the above strategies, extracts from sample modules for teachers and students have been prepared and are being evaluated. It is stressed that these modules are in outline form and require more refinement, proper testing and evaluation. (The topic of measurement has been applied to three vastly differing fields of general worldwide interest - the motor car, the pharmaceutical industry and the construction industry.)

Students and teachers in countries at all stages of development should find the subject areas of cars, pharmaceuticals and buildings interesting and relevant. Block diagrams of the modules on these topics so far prepared show the many ways in which measurement occurs in science, mathematics, technical and vocational subjects. (See Appendix A.)

In addition, slides with commentaries for use by teachers and students, illustrating the all-pervading nature and the importance of the topic of measurement have been prepared. Some of these are currently being evaluated and it is hoped that after further development work, a comprehensive set of material for teachers and students will be available to Commonwealth countries. (An extract from the tape-slide programme is shown in Appendix B.)

Preparation of Interrelated Modules

The following guidelines on the preparation of inter-related modules are based on experience gained in the development of the modules on measurement. It must be emphasised that there is no unique 'modus operandi' in this process and teachers will use the most appropriate method, depending on the resources available and the conditions prevailing in their own countries.

Preliminary discussion should be held amongst teachers regarding the need for an interrelated approach in teaching within a certain topic area. This should identify a topic which lends itself to an interrelated treatment in the form of a module(s). Once a decision to produce a module(s) is made the following steps to develop it may be taken. It is essential that clear objectives, based on sound educational principles, are adhered to in the development of such a module.

Guidelines:

- Assemble the 'teaching team'
- Outline the plan of action using a flow/schematic diagram, decide the title (which may be revised), and set the time schedules for module construction

- Define the target student group (age, range, pre-requisite knowledge, type of educational establishment)
- Formulate general and specific objectives
- Produce motivational material to show teachers and students the relevance and interrelationships of the topic

Note: this could be achieved through illustrations, purposeful in style and related to practical settings. Suitable material could be obtained by:

Contracting commercial/industrial establishments to gather advertising, audio/visual materials

Seeking the co-operation of parents of students to obtain support material/equipment

Encouraging teachers and students to explore the local environment for pictures, specimens (biological, physical, chemical, geological and ecological); and locally available material in order to make low-cost equipment to support the practical content of the module

- Allocate the following to the members of the team as individual or group assignments:

preparing motivational materials in the form of texts, charts and tables

pictures (in colour or black and white)

overhead transparencies

slides/audio tapes

films/video tapes

teacher modules in text form (with diagrams, illustrations)

student modules in text form (with diagrams, illustrations)

- Assemble selected draft material, ensuring that the key points in the modules are suitably highlighted
- Discuss the final draft within the team and consult external bodies/persons. Modify as necessary
- Formulate procedures for testing and evaluation in a 'Pilot Study'. Agree procedures with students/teachers/parents/education authorities and any other parties whose involvement is essential for the success of this approach

Note: It would be highly desirable to supply at least one original set with the multiple copies, so that participating teachers and students could see the module in its original form

- Test the final version before making it available for general use
- Explore the possibilities of getting the module published so that a larger body of students and teachers could use it

Implementation of the Programme

Provision of suitable accommodation should be given high priority in the initial discussions by the team. It is possible that a room suitably equipped to teach interrelated modules may not be available for some time. However, it must be stressed that much can be achieved with few resources given the right enthusiasm and careful planning. Suitable in-service training programmes for teachers should be provided to make each member more familiar with disciplines other than their own. Allocation of time for in-service training and extra-curricular activities may have to be made available within the normal working day.

The availability of resources is bound to vary and it is quite conceivable that extra funds may not be immediately available to purchase equipment. The teacher should study the feasibility of using available resources in the most efficient way - this would certainly require co-operation and assistance from teachers outside the team.

Assessment should be discussed to formulate an appropriate scheme although this may not be possible at the commencement of the programme. After some experience of teaching the module as a team, methods of assessment should be suggested, tried and modified in the light of feedback.

Role of Educational Technology

The use of educational technology has been stressed throughout this paper. Such methods should be adopted whenever possible by teachers everywhere so that their students find some excitement and interest in the presentation of the modules. Many teachers, particularly from countries in Africa and Asia, would argue that some of these facilities are not available to them. Such problems must be recognised but it is suggested that education authorities would be more willing to provide educational technology equipment if they are convinced that its use is essential and beneficial to new and innovative teaching methods.

Distance Learning Methods

It would be a great pity if good and interesting modules were developed by an enthusiastic team of teachers and were not made available to a large body of teachers and students in other parts of the continent as well as other countries in the Commonwealth. One way to achieve this dissemination would be through well produced and attractive teacher/student modules published at a subsidised cost. Another method would be to exploit 'distance teaching' strategies which are finding great prominence in many parts of the world. These strategies would have to be employed on a large scale for the pre- and in-service training of teachers.

Modules - Early Experiences

A number of topics have been evolved and tested with the help of students and staff at Burleigh College, a British comprehensive Upper School with students for the age range 14-18.

One of the projects involved 15 year old Engineering Science students who were asked to design and make a device capable of counting 50 tablets. This project involved students producing finished articles using mainly "junk" materials at very little cost, and illustrated that projects associated with an interrelated approach do not always require expensive equipment and materials in order to be successful.

As a result of preliminary work on the interrelated teaching of a number of topics the following observations can be made:

- We found that an interchange of ideas between teachers brought about mutual understanding of how various curriculum areas operate in terms of classroom management, teaching techniques and syllabus content. It enriched the knowledge, and broadened the experiences, of the teachers involved.
- We noticed that with a team of teachers working together on a topic, students obtained a variety of ideas and opinions from a number of people with different skills and interests. This promoted much discussion.
- The enthusiasm shown by the staff involved in the project produced enthusiasm amongst the students.
- We found that, in order to produce modules which were both stimulating and well structured, we needed: time to meet, discuss and thoroughly plan; time and modest resources to produce/obtain well presented, appealing materials for students; and time to evaluate the work, paying special attention to comments/suggestions made by students.

- Modules/projects currently being tested have generated much interest from teachers not involved in their planning.

Measurement in the Construction Industry

The assistance of the experimenter was requested by a Building Department Tutor in the teaching of mathematics as relevant to Craft Bricklayers under a Youth Training Scheme. After discussions it was agreed that an 'interrelated' approach for teaching these students be adopted and a module was prepared.

Students: 18 in class; 16-18 years of age
Duration: 8 hours
Venue: Wirral Metropolitan College, Merseyside,
England
Aims of Module:

- (a) Study of measurement through calculation, and discussion using relevant quantities in practical situations.
- (b) Establish an appreciation of the interrelationships which exist between mathematics, science and technology involved in the subject.
- (c) Encourage a sensible approach to calculations in respect of rough estimation, approximation, interpretation of results and the use of calculating aids.

The great interest generated amongst students and staff in the above experiment resulted in the experimenter being invited to show the programme of slides on 'measurement' to members of the Numeracy Sub-Committee of the North West Regional Advisory Council for Further Education. The latter's interest has also resulted in requests to try out the module of study with another similar group.

Conclusion

A case has been presented in this paper to teach science, mathematics, technical and vocational subjects in an interrelated manner to overcome the deficiencies and gaps in the way these subjects are currently taught. Students will find relevance and meaning in topics taught this way, in addition to the enjoyment and interest that will be generated. The salient features of an interrelated approach to the teaching of mathematics, science and technology through specially designed modules are summarised on the next page:

- (a) Measurement is identified as an all-pervading topic in science, mathematics, technical and vocational subjects and as such is an ideal topic for development as an interrelated module.
- (b) Appropriate teaching strategies, based on sound educational principles are developed as an essential part of an interrelated modular programme. The terms of reference and suggestions for the implementation of such a programme are proposed.
- (c) Team teaching is advocated. This has a most important role to play in the successful operation of a programme based on an interrelated approach.
- (d) Examples are provided of motivational material for use by teachers and students using educational technology to amplify some of the strategies highlighting the links between subject groupings.
- (e) Formats for teacher and student modules are suggested. Hints and guidelines for teachers and students have been provided.
- (f) In-service training is essential for the success of innovative curricula. Urgent steps will have to be taken to enable teachers to communicate with each other in order to become conversant with the new ideas.
- (g) Distance learning methods would be useful in implementing the programme for in-service training on a large scale.
- (h) Guidelines for constructing further modules are suggested based upon the experiences in producing and testing the modules under development.

Acknowledgements

The paper is concerned with an innovative method of teaching which requires much dedication and team effort on the part of those who believe in the pursuance of such an idea. I am indebted to two of my current research students, Mr. Stanley Turner and Mr. Rodney Bond, who are practising teachers in a college of further education and a comprehensive school respectively. Both of them have taken up my original idea with great enthusiasm and have been developing and trying material for teaching science, mathematics, technical and vocational subjects in an interrelated way. These trials have naturally involved students at school, at technical/vocational college level, as well as teachers who teach them. I wish to express my gratitude to these students and teachers who have

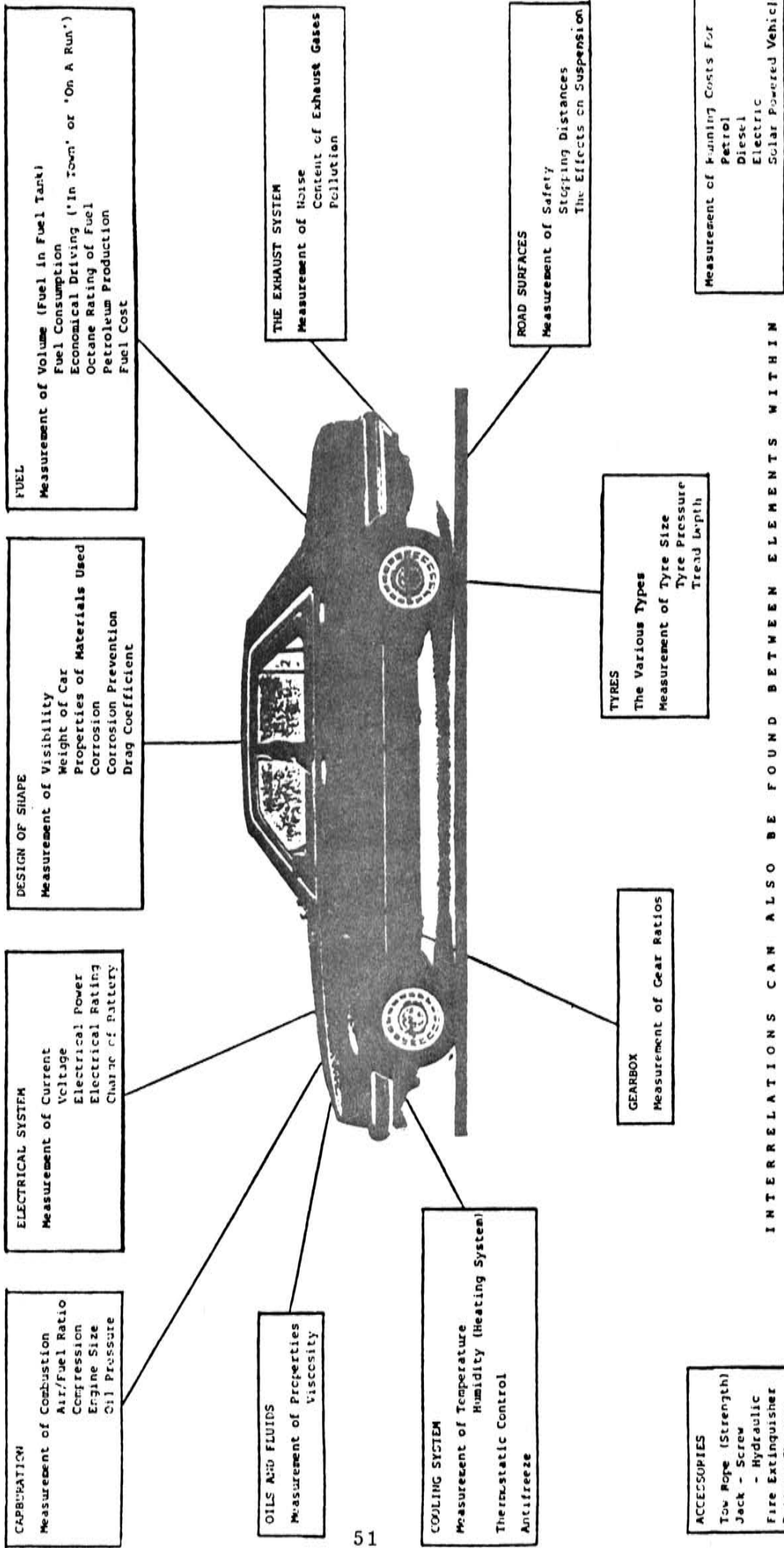
participated in the 'pilot studies', and also to the education authorities, parents and people from industry without whose help the experiment would have had no chance of success.

Note: The diagrams that follow have been prepared by the experimenter and his assistants.

MEASUREMENT AND THE MOTOR CAR

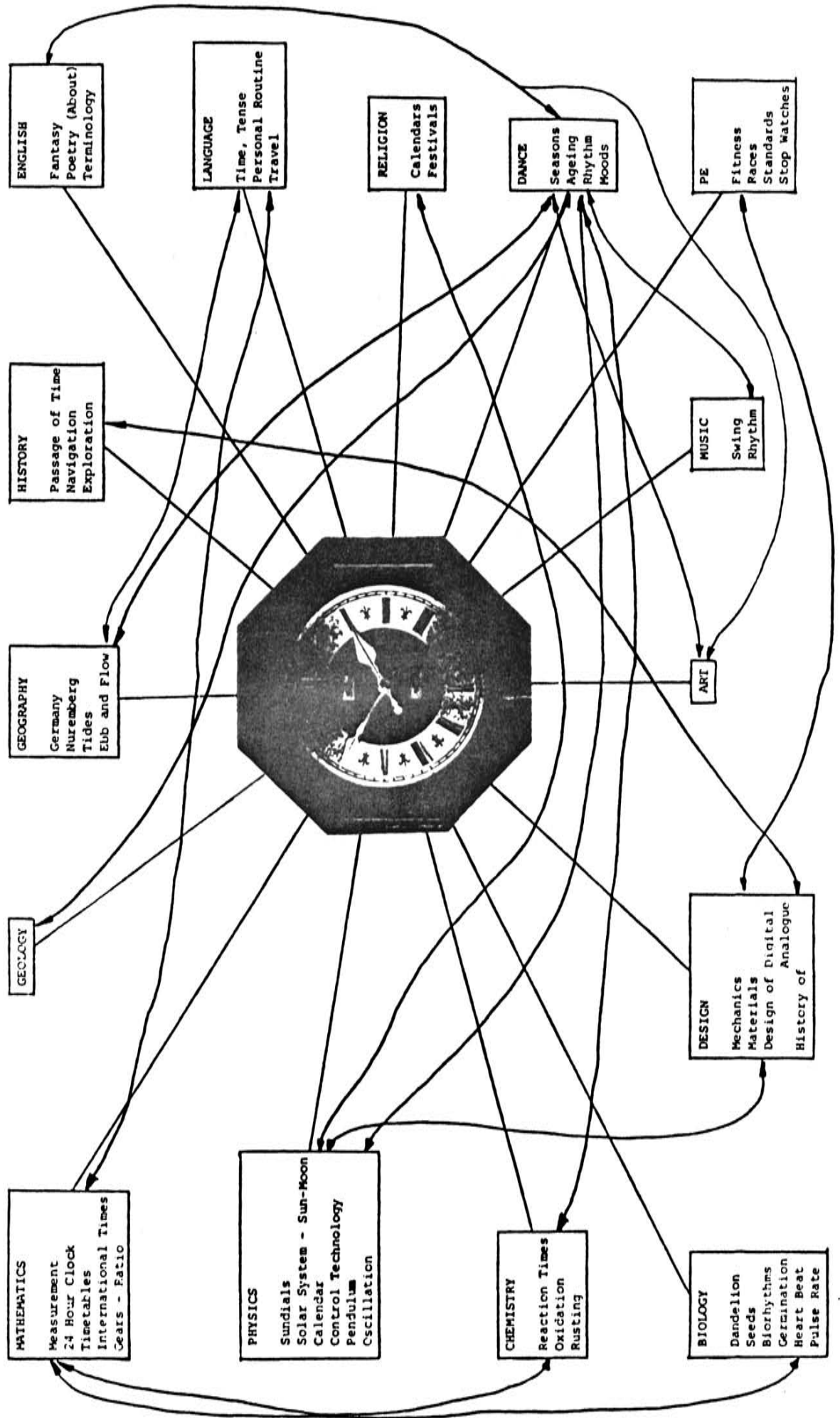
APPENDIX A

Measurement is concerned with: Speed, Distance, Time, Power, Rotation, Capacity, Temperature, Current, Voltage, Pressure, Noise, Pollution, etc




INTERRELATIONS CAN ALSO BE FOUND BETWEEN ELEMENTS WITHIN DIFFERENT RECTANGLES

INTERRELATED STUDIES - BRAINSTORMING SESSION ON CLOCKS




MEASUREMENT IN THE CONSTRUCTION INDUSTRY

S T U INTERRELATED I E S




COATINGS

- Internal, external
- Anti-pollutants
- Structural protection
- Surface protection
- Membrane waterproofing
- High performance coatings
- Appearance



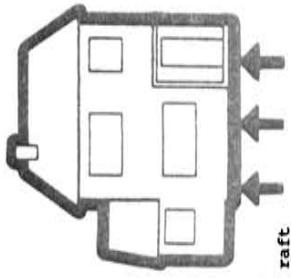
WALLS

- Weight on foundations
- Bricks, blocks
- Cavity fillings
- U-values
- Sound insulation
- Protection
- Finishes




MATERIALS

- Water
- Cement, aggregates
- Steel, wood, glass
- Polythene sheeting
- Sundry fittings
- Tools and measuring equipment
- Transportation
- Site offices
- Amenity buildings




FOUNDATIONS

- Ground survey
- Site clearance
- Site preparation
- Biological treatments
- Excavation and filling
- Protection of concrete raft
- Removal of earth



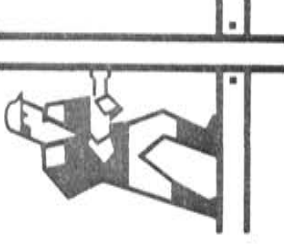
PLANNING

- General outline
- Selection of site
- Local Authority constraints
- Costs: construction, running, maintenance
- Detailed plans
- British Standards
- Tenders
- Contractual agreements




SERVICES

- Initial access roads
- Water
- Electricity
- Gas
- Ventilation
- Waste disposal
- Permanent access roads



STRUCTURES

- External loads
- Floor loads
- Calculation
- Prediction of performance
- Stability: extreme climatic variations
- Steel, concrete



ROOFS

- Effect on foundations
- Thermal insulation: U-values
- Skylights
- Material
- Flat or angled

APPENDIX B

An Extract from a Tape/Slide Programme of 48 slides based on "Measurement" to illustrate INTERRELATED STUDIES

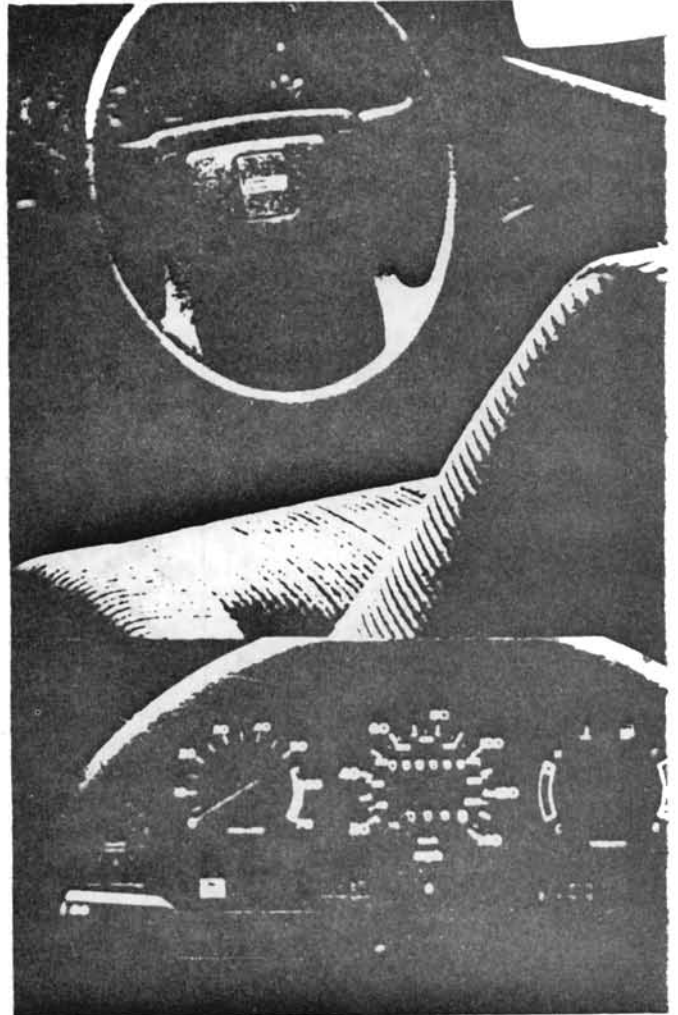


Slide 10*

Commentary for Slides 10 and 11

The wing is clamped so gently that the butterfly flies away, leaving a record of its wing thickness. Technology has been involved: the biologist and the butterfly are pleased.

*Slide 11 not shown



Slide 29

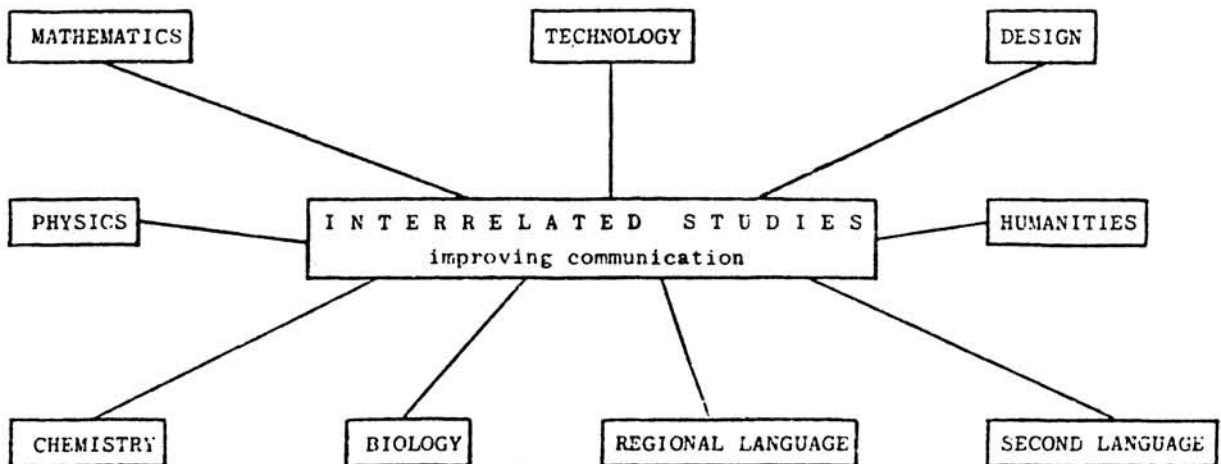
We combine basic measures to form one new time and distance combination to give speed. Each car has a speedometer and also instruments which measure for example temperature, volume of petrol, the charging state of the battery and the rotational speed of the engine in revolutions per minute...

one of
nature's package
deals...

Slide 47



Every industry requires teamwork to produce the finished product. If they wish to achieve harmonious, efficient production then the parts of any industry must come together as naturally as nature brings together the segments of an orange.



Slide 48

Within schools throughout the world, to teach mathematics, science and technology in separated isolation may prove to be a worthless, meaningless exercise for many. If we can prove to our students that what we are asking of them is relevant to their existing and future experiences then we may generate both enthusiasm and interest. By relating our work in schools to actual everyday things we cannot treat subjects in total isolation. The products of today's society requires a marriage of science, mathematics and technology. For many students within schools an inter-related approach may be the way forward - the way in which their curriculum takes on a new exciting look. If, using this approach, we can arouse curiosity and generate interest then we will have achieved a great success in communicating through INTERRELATED STUDIES.

CHAPTER 4: INTERRELATIONSHIPS OF CURRICULA AT SECONDARY LEVEL J. Holbrook and J. Grant*

Introduction

The rapid development of scientific, mathematical and technological knowledge over the last few decades has led to many changes in lifestyle in many countries. Calculators are commonplace in many classrooms, computers are invading commercial and business practices and satellite communication around the world is no longer a dream.

Education within schools must change to take account of these new developments and to prepare students for the real world of the 1980s, 1990s and into the 21st century. Yet changes in school education that have already been introduced - in the waves of curriculum development in the 1960s and 1970s - have not been wholly successful. Mathematics has suffered from methodological problems (e.g. the 'new' maths. versus the 'old'), teacher reticence and remoteness from reality. Science has suffered from an identity problem (the separate scientific disciplines versus a holistic view), a tendency to trivialise (e.g. by equating science with a series of 'experiments') and a tendency to teach facts rather than processes. Technology has suffered from oversimplification (often being equated with manual skills and reserved for the 'less academic' students) and from a lack of clear objectives. All too often the science class is expected to apply mathematical knowledge not yet covered in the mathematics class or the method of approach adopted by the science teacher differs from that taught by the mathematics teacher. Technology is seen as a subject for specialist rooms with large expensive machinery rather than any degree of emphasis on an extension of cognitive skills. Furthermore, discontinuities occur when young people move from primary to secondary education through lack of a total view of the curriculum for students in favour of a discrete division of educational packages at primary and secondary level. But, above all, a huge gap tends to occur between the science, mathematics and technical skills in the classroom and those needed for the world of work.

Curriculum Overlap

An examination of curricula from several countries shows that within a given subject area there is evidence of: common content, similar objectives and similar teaching methods. Thus at junior secondary level in science many curricula have topics in energy, particles, living things and measurement. Likewise, in mathematics there are topics such as angles, statistics, indices, coordinates, ratio and proportion, mensuration, algebra and Pythagoras occurring widely.

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Not only is there considerable similarity between curricula in various countries, there is, across the subject areas of science, mathematics, technical and vocational curricula, evidence of common content, objective, and teaching methods. For example, it is easy to see overlap in such areas as energy, electricity, materials, health, and the use of measurement. In each case these topics occur in two or more of biology, chemistry, physics, engineering science, health science, human biology and design and technology curricula in many countries.

Besides overlap of content, there is also considerable overlap of objectives. The ability to apply understanding to new situations is a feature of many curricula; so also is the ability to analyse and deduce from experimental results. The acquisition of skills and techniques and the ability to communicate results in written or graphical form are specifically mentioned in many curricula and in many countries.

Thus there are opportunities between countries, but more particularly within countries, for links in science, mathematics, technical and vocational curricula. Interrelated curricula are desirable because

- (a) each of the individual subjects is a component of the curriculum, even if not necessarily so for all students; each adds to the sum of knowledge and each cannot be taught in its entirety;
- (b) the subject content and the objectives for the separate subjects invariably, even if unintentionally, overlap;
- (c) the knowledge and skills applying to each subject area, no matter how elementary, will be called upon in everyday life;
- (d) each subject has much to gain from each other - in other words, the whole is more than the sum of the parts.

Interrelated Curricula - Content and Concepts

The linking of present subject areas, although a useful exercise in uniting the education of the student, may not be at the heart of the problem. A marriage of science and technology has been consummated in society, but this is rarely achieved in the classroom. If science and technology education are to be more relevant to society then they should be concerned with the topics with which society is concerned. For the average citizen

to be equipped to function in and contribute effectively to life in an increasingly technological society, it will be necessary to ensure that he or she is not only able to read and write and to count and calculate, but also to manage the materials and processes of technology.

These materials and processes, which of course affect national development, include health, food and agriculture, natural resources, nutrition and sanitation, energy, transport, population control, industrialisation and technology information systems. Very little attention is given to these areas in current science, mathematics, technical and vocational curricula. In other words, the curricula of the future must be less inward looking and more conscious of how science, mathematics and vocational subjects learned at school relate to society, to the world beyond the classroom or the laboratory.

The overall message is to devise curricula that have as the main aim education for the improvement of the quality of life. At the basic level, quality of life means a life which is healthy, free from disease, which implies an adequate supply of basic foods, adequate nutrition, housing, shelter, clothing, clean water and hygiene (sanitation). It also implies the understanding of the dignity of human relations and an appreciation of attitudes to work and community. At the more sophisticated level, it implies aesthetic values - a pleasing environment with acceptable interactions between people and nature (ecology). The aesthetics of urban and rural communities will be different, but both depend on social ambience and an understanding of the work environment and community development. At all levels, the quality of life is enhanced if the individuals in the society can better understand their environment - and can develop satisfactory attitudes towards each other and towards the work environment. It can also help individuals to make decisions and choices about this environment and way of life.

Major conceptual or subject areas can also be considered in an interrelated way. Typical areas are: energy, resources/materials, communication and measurement.

In considering energy interrelationships, science lessons should concentrate on the uses of energy and the interchange of forms of energy rather than the definition of energy as such. Graphical communication would be the main mathematical contribution, whilst technology would consider the control of energy. Safety, social, environment, personal and economic aspects of energy would be treated by all subjects in linking the concept with society.

In considering resources/materials, science lessons would emphasise the availability of local materials and how they are obtained, whilst the mathematics would concentrate on measurement of manufactured resources. Technical studies would highlight the use of local materials and the skills used in manufacturing articles.

Communication in its many forms is clearly a unifying interdisciplinary topic for the school curriculum. It encompasses oral and written skills and the acquisition of the vocabulary of science, mathematics, technical and vocational subjects. Graphs, spatial and numerical skills, and skills related to the representation of qualitative ideas and the analysis of data can all be interrelated within communication.

Measurement, in the area of science, is linked to observation and comparison. Extensive use of estimation is seen as important to all disciplines and this aids interrelationships. Estimation leads to a feeling for quantity, size and proportionality and would be stressed in mathematics. Practical use of measurement is emphasised in technical and vocational subjects.

Objectives for Interrelated Curricula

Common objectives and teaching methods are also important in the interrelation of subjects. In terms of objectives there will be common cognitive skills, practical skills, and attitudes; these will lead to teacher practices based on problem solving, inquiry, discovery, as well as in basic methodologies of teaching. Much interrelating of curricula can be based on problem-solving approaches. A study of the problem-solving steps commonly used in technology can provide an interesting basis for interrelated approaches. In this sense the relevant steps are:

- | | |
|---------------------------------------|--|
| Data collecting and processes | - linked to mathematics |
| Market surveys | - linked to mathematics |
| Ergonomic studies and experimentation | - linked to science and mathematics |
| Mathematics of materials) | |
| Environmental/economic/ethical) | - linked to science |
| social/political researches) | |
| Proposed design solutions) | - linked to mathematics |
| Selected of best solutions) | and science |
| Choice of materials and production | - linked to science and vocational studies |
| Mock-up simulations | - linked to vocational studies |

Proposed solutions/refinement	- linked to science
Finalised design, solution and execution	- linked to science, mathematics and vocational studies
Testing	- linked to science and vocational studies
Communication	- linked to science, mathematics and vocational studies

Approaches to Interrelated Curricula - Implementation

A commitment to interrelation need not necessarily imply a threat to traditional subject disciplines. There could be three broad approaches to implementation of interrelated curricula:

- (a) An attempt to co-ordinate the introduction of common concepts in the various subject areas,
- (b) The introduction of an 'integrated studies' component into the curriculum (probably based on problem-solving),
- (c) Re-organising the whole curriculum so that the subjects lose their separate identity.

A school might decide to adopt for the present only the first method so as to assess whether the outcomes are positive. Indeed, this may be the preferred approach where there is a strong tradition of separate subjects. If the experience proves beneficial, it could lead to the development of further ideas for the interrelation of subjects.

To initiate any such interrelation within the school, two basic approaches appear possible. The first is for committed individual teachers to set about showing how this can be achieved in their own schools and classrooms. Any success achieved would be likely to attract other teachers to seek similar results. The second is for the whole school or school system to adopt a planned approach to the interrelation of subject areas.

The first approach utilised a concept commonly adopted as part of the rationale for in-service training. This is to develop in selected individuals (school co-ordinators) certain skills which, it is hoped, they in turn pass on to others by their example and influence in the school. It is a model which has become less favoured in many places because of the inertia in the system which individuals find difficulty in overcoming.

It takes a highly competent and charismatic individual to achieve change in an institution or a system without organised support. A way must be found to encourage such teachers, for example, by giving them access to special resources, giving them time for carrying out the tasks and perhaps awarding financial incentives. The importance of an active professional teacher association cannot be understated in giving both moral and material support to such teachers. Frequent contact with outside organisations also plays an important role for both encouragement and feedback. Where such systems have been encouraged, success has been shown to be very dependent on the enthusiasm and support of teachers.

The second approach is only likely to be effective if it is not imposed as a fait accompli, but rather seen as a movement which involves the co-operation of all participants. Again the support of teachers cannot be overemphasised. In a given school a typical approach might be as follows:

- (a) An evaluation of the curriculum would be undertaken to determine the extent to which it is meeting student needs. This evaluation should involve all staff of the school with outside assistance only when necessary.
- (b) The interrelationship of subjects would arise as part of this evaluation and information should be available to the school from outside curriculum units to suggest ways of improving the subject areas.
- (c) The school should decide itself how it wishes to improve its curriculum and it may decide to adopt any of the basic methods of interrelation mentioned above.
- (d) Support should be available to assist schools in their efforts by way of staff development programmes, curriculum development expertise and appropriate curriculum materials. Morale boosting must be seen as essential.
- (e) The examination methods used must ensure that they allow for the assessment of interrelated knowledge and skills.

Pre-service teacher education will, of course, have an important bearing on what is taught in schools. Consequently immediate attention should be given to breaking down rigid subject boundaries in the preparation of teachers and to developing teaching techniques which integrate the knowledge and skills in practical ways. In-service education of practising teachers must be seen as crucial at the same time so that:

- (a) experienced teachers take a leading role in new educational developments,
- (b) new, inexperienced teachers are not disillusioned on entry to schools by the attitude of teachers,
- (c) better links are established between schools, and curriculum development units.

Organisational Aspects

Success in any educational process depends ultimately on the teacher. So often, in the past, many projects have failed to attain the desired objective owing to a failure on the part of teachers to appreciate the philosophy behind the change or through lack of teacher enthusiasm for implementation of the project.

The morale of the teacher is crucial to curriculum development. Organisational support is required to boost this morale. In one aspect this means linkage of teachers and teacher educators through science teacher associations at the national level and through organisations such as CASTME (Commonwealth Association of Science, Technology and Mathematics Educators) and ICASE (International Council of Associations for Science Education) at the international level.

In another sense the morale of teachers can be lifted through an adequate organisation of support facilities. Sufficient resource materials and back-up facilities such as use of the mass media are essential for maintaining the enthusiasm of the teacher and encouraging effective teaching. Active encouragement and support should also be given for teachers wishing to improve their teaching.

Guidelines for school planning should provide for bringing teachers together. It is only through working together on the analysis of objectives, content and teaching practices that common understandings will develop and the interrelationship of subjects brought about. Given that teachers rely to a large extent on learning materials which are developed outside the school, it will also be necessary to bring together the curriculum developers and textbook writers from the various subject areas, setting them the task of devising projects of discovery, inquiry and problem solving which can assist teachers once these teachers have made some commitment to the interrelationship of subjects.

To facilitate the development of interrelated curricula at the junior secondary level, it may prove beneficial to consider adaptable, non-specialist rooms that can serve for practical work, data collection and design activities. Such activities can, of course, also be conducted outside the classroom. In this way constraints on time allocation for the various disciplines can be minimised and the heavy reliance on specialist apparatus and machinery is avoided. A greater reliance on project work at the upper secondary level may have a similar effect particularly towards the end of the course where the knowledge and skills learned can be interrelated between subject areas.

The interrelating of subjects should be encouraged through the appointment of teachers to co-ordinator roles. In-service education opportunities for co-ordinators should be considered of vital importance and the co-ordinator seen as the major agent of change within the school. The co-ordinator should initiate and continue school-based-in-service education for other staff and this should be a planned activity on the school timetable. The curriculum should take into account the requirements of both the local situation and any external examination and maintain a balance between them. Serious consideration should be given to school-organised curricula which would reflect the interests of the individual teachers and thus make better use of such expertise and boost morale. Where school curricula are seen to remain isolated and not in keeping with developments, then persuasion through outside motivation and in-service education, especially through co-ordinators, should be encouraged. In this development the head of the school must assume an important responsibility.

CHAPTER 5: THE DEVELOPMENT OF PRACTICAL PROBLEM-SOLVING CURRICULA FROM TRADITIONAL CRAFT CURRICULA
Peter Bleakley

Introduction

The transition of technical curricula to practical problem-solving curricula (often called the "design and make approach") may be divided into two main phases:

- (a) The curriculum development phase in which technical subjects are reviewed, syllabuses developed, tried and evaluated, and
- (b) The wider implementation phase.

The experience of many countries has emphasised the need for setting up administrative procedures to facilitate the change and the allocation of finance to support a development phase of three to four years. Wider implementation will require in-service training and more resources. The readiness of teachers to accept change, the needs of pupils, the support of education authorities and the expectations of the community must all be taken into account when converting school workshop and technical drawing curricula into design and make concepts.

Definition of Terms

1. The traditional approach: The traditional approach to teaching woodwork is often teacher-dominated. Concern in the workshop with safety procedures, workshop organisation, workshop management and maintaining control of the pupils tend to overshadow the learning objectives of workshop subjects. The teacher selects the article to be made from a source of well-tried and proven plans, makes alterations, decides what material should be used and how the article is to be finished. He organises the production sequence, demonstrates each process, and guides the class step by step in the manufacture of the article. Workshop teachers feel confident within this lock-step teaching process in which the whole class produces the article. Great emphasis is placed on the finished product and in many instances principals and parents judge the effectiveness of the manual craft teacher by the standard of the completed article. Where relevant, theory is used to complement the practical component of the course. Technical drawing subjects tend to emphasise plane and descriptive geometry, and pictorial and applied drawings. The technical drawing curriculum rarely prepares pupils for industry where

drawing is used as a design instrument to solve practical problems. Instead, the subject is generally taught as an academic discipline in graphic communication and may not even be interrelated with the pupils' practical work in school workshops. Such a tightly directed teaching approach causes a corresponding lack of involvement and commitment by the pupils and it deprives them of opportunities for personal growth and development. The learning process is reduced to a programme where they are told everything and discover little. Because pupils are protected from the decisions that are implicit when making articles they are ill prepared to make those decisions at the end of a traditional course.

2. The practical problem-solving approach: The practical problem-solving approach aims at involving pupils, to an extent that their readiness permits, in all the development phases of a product. Pupils in this situation are presented with a design or project brief which clearly states the practical problem to be solved and includes any specifications which the teacher considers necessary. Design briefs can originate from a number of real situations or genuine needs and may range from the simple to the very complex. Design briefs may be craft-oriented, such as design and make a storage unit or a chair. These briefs are concerned with craft skills and craft technology and encompass the type of design problems which can be realised in the school workshops with a technical teacher. In essence it is product design.

Design briefs may also have a technological bias, such as design, and make an instrument for measuring wind velocity, or a solar water heating unit or a burglar alarm. Such projects require technological skills and knowledge, and their design elements overlap with the disciplines of science, particularly physics. This kind of project work fosters the interrelation of science, mathematics, technical and vocational curricula. Ideally, the teacher would have a good background in all these subjects, as well as in design. Design briefs can also be a combination of both craft and technology. In this approach the student develops design skills, including:

- (a) Investigation: ability to recognise a problem and search for a solution. This activity includes searching for information, experimentation, and using analytical skills and judgements to reach sound conclusions.
- (b) Invention: ability to initiate and develop ideas, and to adapt existing solutions or complete a partial solution. Invention includes the complementary communication skills of drawing and language.

- (c) Implementation: ability to organise and plan the construction of a prototype within available resources.
- (d) Evaluation: ability to discriminate and critically to appraise the merits and shortcomings of the finished product.

Skills and knowledge are taught as the need arises and therefore at a time when the student is strongly motivated. Technology studies are closely related to the needs of the pupil to design and make an article. Students are encouraged to make decisions and be responsible for them. However, the teacher's role - to teach, guide, counsel and approve - is of critical importance if students are to experience satisfaction and success.

The traditional disciplines of craft skills need not be sacrificed in the practical problem-solving approach. However, craftsmanship skills and technical knowledge are no longer the main criteria for the assessment of pupils taking a practical course using a design and make approach. As part of this approach the traditional content of technical drawing is extended to include design work where pupils can be presented with abstract and practical problems. Imagination and inventiveness have more scope in this kind of drawing course because designs evolved need not meet the criterion of being capable of construction in a traditional workshop. In essence, the practical problem-solving approach is that of teachers guiding learners towards independence in their learning. The discovery, enquiry, design, creative and analytical thinking, and decision-making - traditionally the province of the teacher - is shared with students.

Steps in Transition - Climate for Change

A significant number of technical teachers believe that some of the traditional outcomes of the technical curriculum should continue because tool skills and technical knowledge continue to be important for future careers and for leisure activities. At the same time there is a growing awareness that the potential of technical education is not being used to meet the general educational needs of students. The relationship between tool skills, technical knowledge and creative thinking should be investigated by curriculum designers in order to tap this potential.

Traditional vocational links in technical education tend to limit the intake to technical courses to the middle and low ability spectrum of the school population, who usually aspire to

be tradesmen. The technical institute system established for the craftsman and technician is now well established in a number of countries and this provision tends to free the secondary sector of its previous role of preparing pupils for particular vocations. Although vocational links are still important there is a growing awareness that all students need to develop knowledge and skills about materials, tools and processes as a component of living and as a balance to the academic bias in their education. Conflicting philosophies about the future role of technical education emerge as schools and teachers take different attitudes on a number of issues affecting technical subjects. Indeed, technical education seems to be going through an identity crisis.

Design as a creative and disciplined decision-making process is in contention with the acquisition of tool skills using set projects and prescribed knowledge. A greater response and understanding from students are needed if they are required to design and implement a solution to a practical problem. Breadth of knowledge taught as a component of general education is in conflict with depth of knowledge required for vocational purposes. Self-learning and enquiry methods of teaching are in tension with closely controlled teaching situations.

The flexibility of open-ended curriculum statements is opposed by the desirability of definitive content-based statements. The internal assessment of pupils taking a practical subject for a national certificate confronts the traditional assessment by external examinations. These issues are likely to divide technical teachers, but they also cause teachers to think in fundamental terms about the purpose of technical curricula in schools.

In this uncertain flux of technical education some educational authorities are expressing dissatisfaction with existing technical curricula, and examining bodies are exerting pressure to review workshop subjects. At the same time individual teachers are working experimentally and in isolation on design concept project work. The influence of international developments in technical curricula is also a factor in creating a climate for local change. Technical subjects are caught up in rapid technological change and some countries are reviewing their subject boundaries to update and clarify curricula - in some cases by allowing subject boundaries to overlap with art and science.

One major restraint to design concepts in the technical curricula is the initial opposition of traditional teachers who feel insecure and threatened by the proposed change. Their backgrounds, training and teaching practice have not prepared

them for the significant changes caused by student involvement in design of workshop projects. Education authorities may be faced with a weak or even hostile teacher climate during a transition from traditional to design curricula and this could slow down the rate of change. Because curriculum development work associated with the transition could be influenced by the teacher climate, a small beginning in one subject at one level may be a wise course to follow. Teachers can and will change their attitudes but it takes time and they must be convinced of the rationale for design education in school workshops. The experience of some countries confirms that the involvement of teachers in the change is an effective way of changing their philosophy and attitudes.

The Procedure for Change

Experience in some countries has shown that one effective procedure to bring about change is to concentrate on one aspect at a time - for example the curriculum in school workshops - and establish a developmental committee to review current practices and then to consider and recommend new curricula with all the implications for buildings, equipment, materials and staff retraining. Such an approach may well take several years and there will be development costs for the trials and evaluation required during the process.

Some of the fundamental issues that can be raised when considering a change in, say, workshop practice are:

- (a) What are the deficiencies of present workshop practice and what are the strengths that should be preserved?
- (b) What are the worthwhile activities that students should practice in workshops?
- (c) What are the students' needs for the future?
- (d) How can experiences in the workshop provide for these needs?
- (e) What is society's expectations of students who have a technical bias in their education?
- (f) What attitudes, skills and knowledge are to be encompassed in workshop practice courses?
- (g) Should the emphasis be on process skills and conceptual development or the finished product of the practical work?

- (h) What is the place of practical problem-solving in a workshop course?
- (i) Will future workshop practice courses maintain their craft identity?
- (j) Should applied science have a prominent place in school workshop courses?
- (k) What is the aim of workshop practice subjects at junior, intermediate and senior levels?
- (l) What are the general objectives of workshop practice in terms of attitudes, skills and knowledge?
- (m) Should self-learning skills be one of the educational objectives?
- (n) Is it desirable that students should study and become aware of the influence of technology on the lives of people?
- (o) Should the curriculum be objective-based or content-based or include both?
- (p) Should a modular approach be investigated?
- (q) Is it necessary to have a full set of teaching resources from which schools may choose items to form programmes?
- (r) What materials form the basis of a course?
- (s) Is some form of national assessment necessary? If so, what mark-weighting ought to be allocated to craftsmanship, design ability, knowledge and attitudes? Does this weighting change at different levels of the school?
- (t) How will the curriculum be taught and assessed?
- (u) Is the proposed curriculum suitable for existing teachers with some in-service training?
- (v) Are there expensive implications for buildings and equipment?
- (w) What are the links between the proposed curriculum and other curriculum areas?

There will also be even more practicable issues such as what name is to be given to the new subject, what is a desirable class size and how many hours per week are required.

Pilot Trials of New Curricula

Trials in, say, 10 to 20 schools over a two or three year period are desirable. Such trials must be effectively managed, monitored and evaluated, and the teachers involved will need in-service training to prepare them.

The desired curriculum change is not merely a change in content; it represents a new approach to teaching and learning which implies differences in the facilities and staffing required and different strategies including different workshop management and assessment.

The objectives of the trial stage would include:

- Student reaction
- Viability of proposed curriculum
- Changes necessary to the draft curriculum
- Teaching strategies that encourage practical problem solving
- Programme planning techniques to achieve the curriculum objectives
- Assessment and moderation procedures
- Class management techniques for the management of design briefs in the school workshop
- Whether the draft curriculum is adaptable to the needs of all abilities
- Book and audio-visual resources that support the draft curriculum
- Implications for pre- and in-service training of technical teachers
- Implications for buildings and equipment
- Method of wider implementation

The Wider Implementation of Change

The trial of the draft curriculum should produce useful information on the implications of a full implementation of design curricula in ways appropriate to the indigenous needs of country or state. Such information will assist policy decisions

on whether transition to problem-solving technical curricula is to be accomplished in the short-term with substantial resources or in the long-term as resources permits. Whatever the policy, unavoidable costs will be incurred in meeting the need for in-service and reconstituted pre-service training and the provision of minimal resources necessary to support the new curricula. It is probable that countries will be able to implement design curricula on a limited scale using existing facilities, equipment and local materials. The necessary alterations and extensions to existing facilities can be made on a phased basis as economic resources allow.

In-Service Training

As a result of the trial it should be possible to identify the particular retraining needs of existing technical staff who are to teach, manage and assess the design concepts in the new curricula. These needs will include:

- to understand the philosophy that underpins design education in the technical curricula;
- to develop teaching strategies appropriate for teaching design;
- to understand the design process and develop design skills;
- to plan programmes in which design activity is an integral part of the course;
- to develop design briefs that interest and motivate pupils and allow for alternative solutions;
- to evaluate the design briefs in terms of the course objectives;
- to learn class management techniques in the practical problem-solving situation in the workshop;
- to integrate the study of technology with the design and practical activities of their programme;
- to teach graphic communication skills as part of design sketching;
- to assess design ability.

Technical teachers in post may require the equivalent of a one-week course before they establish design-based courses in their school. A follow-up course in their second year of implementation will consolidate progress and reinforce aspects of the introductory course.

Pre-Service Training and Teacher Qualifications

In order to meet the demands of practical problem-solving curricula it will be necessary to re-structure existing pre-service teacher training courses so that they include:

- design and philosophy of design education
- materials and design
- restructured principles and practice of technical teaching
- programme planning using design briefs and study assignments
- process-centred assessment

Current technical teacher qualifications may need updating to include design aspects of technical education. Some countries have new teacher qualifications of degree status, orientated to meet the demands of design and technology courses in schools. Some of these pre-service training courses with a duration of four years concurrently qualify trainees for a teaching degree and a teacher's diploma.

Resources Development and Production

In the conversion of curricula to design studies some countries have used existing technical education texts. However, there is a need for new material to help teachers of design and technology - possibly in the form of guide-books and textbooks to introduce ideas for design briefs that teachers may wish to develop for their programmes. One country has produced a set of design briefs with related technology in order to help teachers, and there are a number of authors in several countries preparing books of ideas for design briefs. If such material is based on indigenous needs it will provide valuable assistance to teachers during a transition to design curricula.

CHAPTER 6: TEACHER EDUCATION STRATEGIES IN THE INTERRELATED
TEACHING OF SCIENCE, MATHEMATICS AND TECHNICAL/
VOCATIONAL CURRICULA

S. Commissiong and B. Carlisle*

Introduction

Educational development, at the present time, is characterised by two main aims: to enhance the content of education by making it more relevant and to improve the teaching/learning process.

In science, both these aims have given rise to a number of projects which have attempted to link together the concepts and principles into a unified or integrated whole. The curricular materials generally include materials (texts and kits) for the students and guides for the teachers. Often these are so closely tied to the particular curriculum that teachers not directly involved in the project concerned have been only marginally influenced. It has also been observed that when the trial phase of the new curriculum (during which intensive training of teachers takes place) is over, many teachers find it difficult to sustain the rhythm of implementation for a variety of reasons. Much lip-service has been paid to the fact that teachers are agents of change and that central to any development or innovation is the role that they must play in bringing about that change, but little has been done to develop a theoretical framework in support of this role.

Much teaching in the past emphasised content. Today the shift away from teaching facts to teaching skills poses a challenge if not a threat to all who are engaged in the enterprise.

Teaching is essentially a process of developing, clarifying, enlarging and presenting information, ideas and meanings to others. Its ultimate aim is that of preparing pupils for life in the real world. The qualities and skills necessary to do this effectively is still a matter of considerable controversy. However, certain characteristics seem to be agreed upon as part of the reservoir of skills and dispositions that a teacher should possess. These include:

- faith in the ability of people to change;
- an ability to see thematic consistencies in diverse information with skill in organising and communicating these differences;

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- an ability to conceptualise many sides of a controversial issue;
- an ability to learn from experience;
- empathy;
- well developed cognition;
- personal motivation, enthusiasm and conviction;
- maturity.

Much depends on the teacher's ability to manipulate the classroom situation, which in turn depends on how much he knows of his subject areas, how much he understands children's needs in relation to those of their society, and how flexible he is and open to change.

In the planning and implementation of any teacher training programme, consideration must also be given to the needs and concerns of the student-teacher and to the fact that teaching styles are as diverse as learning styles and that the needs of the teacher change with time.

Interrelated Teaching

There is no precise definition of interrelated teaching but the term does imply some form of linking of bodies of knowledge together in a meaningful way. The real difficulty lies in locating the organising centres of such an approach.

There are three possible approaches to interrelated teaching: interdisciplinary, multidisciplinary and transdisciplinary. The first two use the subject or subject matter as focal points whilst the third uses situations as a basis for organising the learning. There is virtue in using all three approaches with the aim of giving students a functional knowledge of the interrelations between the different factors and components and the constant evolution of the natural and human environments of which they are a part. Organising teaching so that subjects are interrelated is a complex undertaking, the magnitude of which cannot be overstated. While situations may be used as the organising centre of the curriculum thus focusing on the learner, there are advantages in not completely discarding the classification of knowledge into disciplines. Disciplines have their own method and epistemology, and by the very nature of their specificity should be treated in such a way so as to preserve their impact on the systematic training of the mind. There is good reason for

retaining them at the secondary level though every effort should be made to de-emphasise the teaching of information as an end in itself and to interrelate subjects by drawing on the various methodologies and explanatory theories of the disciplines concerned.

What do Interrelated Studies Demand in Teacher Training?

Interrelated studies demand intellectual breadth, knowledge and insight from both college tutor and the teacher trainee in training. In any cultural setting interrelated studies in schools will contrast sharply with the status quo, the expectations tutors and students have of teaching, and the popular concept of schooling, its goals and outcomes.

The nature of the change presupposes a number of conditions. These may be summarised as follows:

1. Each teacher trainee has experience of a knowledge structure which interrelates the various disciplines. The experiences of childhood are not gathered into a knowledge system recognisable as disciplines. The interests of childhood and the knowledge gained do not recognise the boundaries of disciplines, at least in the early years. Knowledge is gained from action. Children's thinking flows easily from a preoccupation with factual information to flights of fantasy, moving easily from reality to imagination. The world is one whole, a seamless fabric explored through observation, questions and 'experiments'. Hand and brain work together in an effort to satisfy curiosity and assure survival. The extent and depth of the knowledge structure is greatly influenced by ability, social class and schooling.

Each student has had experience of this interrelated mode of learning in their early years and developed a knowledge structure shared by siblings and comrades within a culture. This memory can be evoked or recognised by observation of children in school. Individuals therefore do not come as strangers to interrelated studies. Indeed it can be argued that these early constructs are the basis for the more formal work of later schooling.

Many young adults have also developed interests and expertise within the pursuit of a hobby in which knowledge is built up in a non-linear way. Such knowledge also stretches across the boundaries of many 'discipline' fields. The natural occurrence of

interrelated studies in the informal learning setting of clubs, museums, art and science centres for both children and adults provides a useful model of observation of interrelated knowledge in action.

2. For most students interrelated studies demand a change in "experiences", that is, a change in the belief structure rather than a change in educational technique (pedagogy). This second assumption would seem to contradict the earlier one and present a paradox. Every student has earlier experiences of interrelated studies, but these are later challenged. The expectation of school is expressed in terms of what is taught and how it is taught. School is a place where one learns "subjects", where time is regulated by succeeding applications of mathematics, science, social studies, art, etc. and where knowledge exists within recognised disciplines. Success is measured in terms of achievement in examinations rather than in terms of the intellectual skills gained or the ability to transfer these skills to everyday life. The accent is on knowing that rather than on knowing how. Conversion to another view of schooling will of necessity be slow and difficult to achieve, for while an interrelated approach is accepted in primary and middle school there is often a resistance to it at the secondary and tertiary levels.
3. Science, and its mode of operation is in conflict with traditional thoughts, and will demand a change of view at both the personal and professional levels. The individual develops from having a simple concept of the world, its physical, chemical and biological "laws" to an increasingly complex and "open" view of nature. While this may be true to some extent in any culture, western societies in general are more supportive of the "open", "scientific" viewpoint even though not all members of the society practice it. Given this premise it is likely that interrelated studies will present a challenge to an established way of thinking and will demand a change of view of many students.
4. Through the teaching of interrelated studies it is believed that students will develop a knowledge structure relevant to experience and readily adaptive and transferable, and a diversity of concepts developed within the context of 'need to know' rather than a formal discipline. In the days of pre-formal schooling the culture was learned through example, observation and practice, and crafts were

learned by apprenticeship to skilled practitioners. By this apprenticeship, knowledge, skill and techniques were acquired as needed and established through continued practice. The awkward and untutored early efforts gradually progressed towards a natural integration of mind and muscle. The knowledge structure was thus organised according to need and practice.

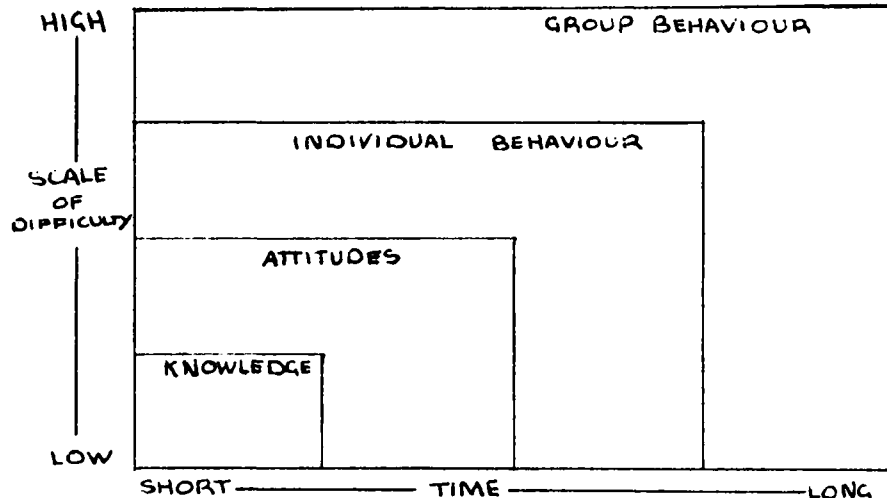
Many parallels between the informal learning environment of childhood and the more structured apprenticeship or adult learning as evidenced in a hobby or avocation can be established. In a hobby such as, for example, photography, knowledge is gained in a non-linear way, the extent and depth of that knowledge being sufficient to solve current problems. The knowledge base is extended when new problems are met. The skills developed are found to match the demands of the task. The individual progresses at his own rate. He controls the rate of his learning and so maintains a sense of competence. This sense of control and the pleasure gained sustain the learning process, ensure attention and perseverance, and maintain curiosity. Repetition of tasks to the point of mastery is a characteristic, often accompanied by overlearning to the stage where understanding is complete and performance of the skill automatic.

This non-linear progression of learning is quite unlike the sequence which would be presented in formal instruction. Knowledge gained by non-linear progression resembles an incomplete jig-saw puzzle, with many gaps, but with many places where the picture can be seen clearly. The jig-saw puzzle analogy can be expanded into a three-dimension model which allows for cross-linkages between pieces while at the same time supporting the idea that there are areas of knowledge which exist in isolation within the matrix.

5. Supervised practice in conducting interrelated studies in schools is a prerequisite to effective teaching. Knowledge built up in this way is highly adaptive, has cultural relevance and is readily available for use or for review. Learning in interrelated studies has these characteristics, but time will be required to facilitate the over-learning necessary to sustain involvement and develop competence.

6. Young teachers need support in schools in order to introduce and maintain interrelated studies. In summary, interrelated teaching demands a change in attitude and behaviour, both requiring time, and a support system which extends beyond the training period. Figure I shows the relationship between scale of difficulty and time.

Figure I Relative Time and Difficulty in Making Changes



Training of Teachers for Interrelated Teaching

In considering strategies needed, it will be necessary to distinguish between pre-service and in-service programmes as well as between different levels at which teachers will be teaching. Allowances should also be made for those programmes which are end-on-courses and for those in which pedagogy is combined with subject content. It is assumed that any programme will include the professional areas of Philosophy of Education, Sociology, Educational Psychology.

1. Organisation of the Content:

As a general aim, the teacher required to teach science related to the fields it services should have the kind of science background that reflects what science really is, a willingness to be innovative, and certain competencies which include:

- a thorough knowledge of at least one of the sciences and a basic understanding of its interrelationship with the technical and vocational fields - for the primary teacher a broad background in the sciences (integrated science preferably) with skill in relating it to art and craft and to the rudiments of other areas in the technical and vocational fields;
- an ability to select and develop or implement curricular materials and strategies leading to desired behaviours in the learner;
- an understanding of the cultural values inherent in scientific activity;
- an appreciation of the role that mathematics plays in the understanding of reality;
- an appreciation of the value of indigenous cultural roots;
- competencies in a variety of teaching-learning strategies and techniques including evaluation aimed at promoting the development of enquiry skills in the learner;
- open-mindedness and flexibility in personal style that accommodates coping with change.

Since student teachers will be entering the course from a variety of backgrounds and interests, it would be desirable to structure the content in the form of modules to allow for different entry points and to facilitate alternative routes through the programme.

A common core of knowledge based on the 'big ideas' or conceptual schemes of science may serve as the main branch with off-shoots leading into the technical and vocational fields. For example fuel, energy, machines, shape and pattern, materials and structures, nutrition, health, time and space, conservation are some of the universal topics that may be used as major themes for interrelated studies.

The materials chosen for curriculum development should interrelate varying bodies of knowledge, reflect the world of work and be based on the 'scientific' approach. Students should learn in ways that they can themselves use when teaching.

There are three levels of curriculum materials:

- Level 1: Individual challenges
- Level 2: Thematic challenges
- Level 3: Integrative challenges

These levels, which are arranged in hierarchical order, are aimed at developing creative thinking, one of the attributes required for interrelated teaching. Creative thinking may be said to comprise the ability to recognise problems, produce novel ideas, organise ideas and evaluate the results.

Examples of these three levels of curriculum materials are:

Level 1: Individual challenges

Specific but small-scale challenges such as to design and use a trap to capture small animals (insects, mice), or to camouflage an object (e.g. a pebble) so that it will be difficult to find.

These challenges incorporate thinking and manipulative skills. All demand knowledge of the phenomena to be investigated, require some quantification and engineering-type design, and often relate to everyday life situations. Each challenge embodies understanding at both the level of first-hand experience and at a conceptual level.

Level 2: Thematic challenges

Individual work is replaced by group activity with problem-solving in a social context. For example, strength of materials can give rise to many interesting problem-solving ideas, e.g. to design and construct a bridge 40 cm long to hold at least 1 kg using only 150 wax paper drinking straws and an unlimited supply of straight pins.

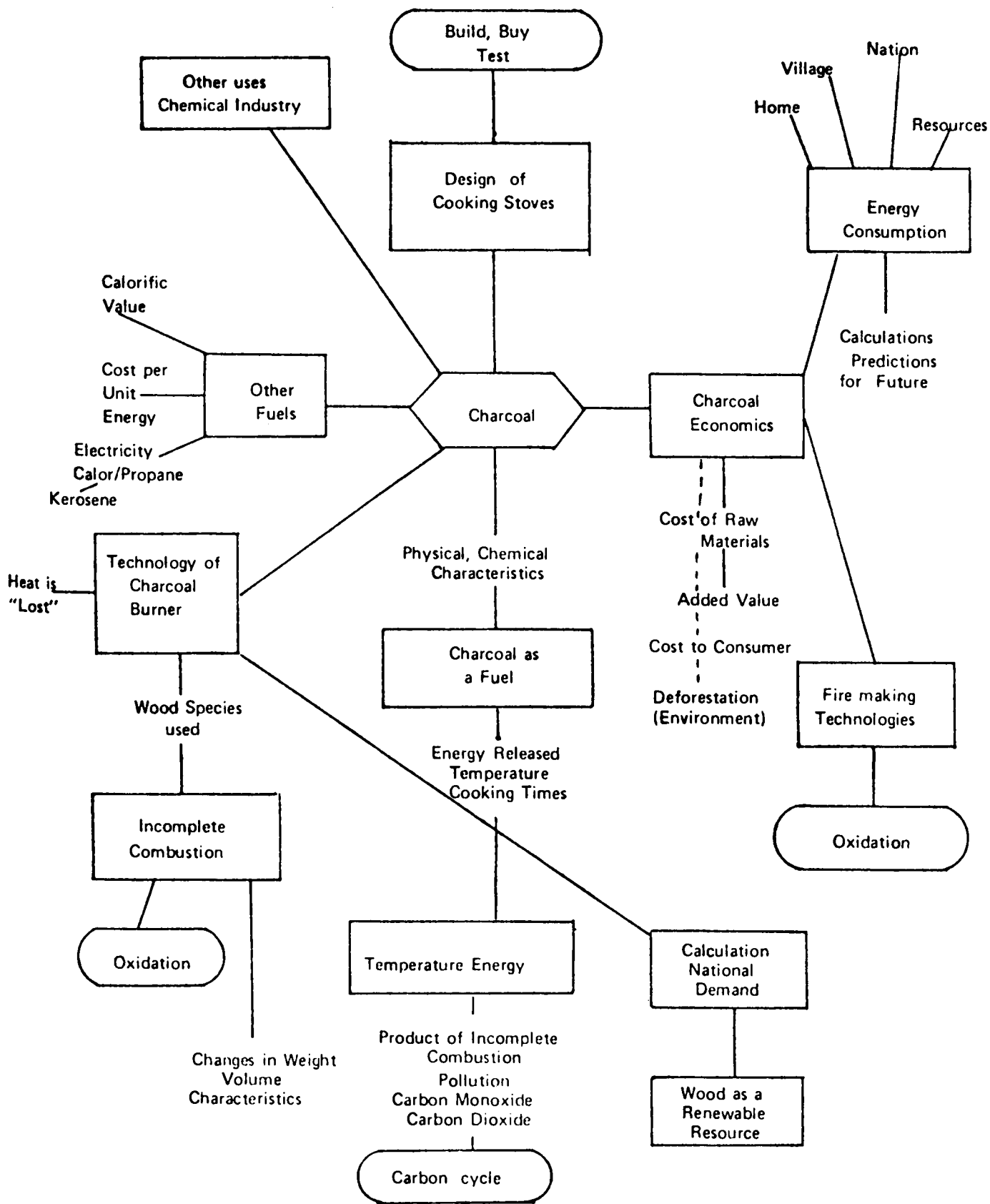
Level 3: Integrative challenges

This is the most complex array of challenges and is integrative in the widest sense of bringing together ideas which are from varying fields of human knowledge, thus providing for both tutors and students an opportunity to build a network of themes relevant to local conditions.

One example, shown in Figure II, is Charcoal, an Interrelated Unit.

FIGURE II

CHARCOAL - An Interrelated Unit



2. Strategies of delivery

How is information acquired and presented? A proposed strategy involves team teaching across subject boundaries as a method of presenting the teacher trainee with information through lectures, demonstrations, projects, seminars and workshops. The student-teachers will, however, play an active role - selecting topics and materials - rather than the passive role of receiving information.

For team-teaching to be successful, a knowledge of group dynamics which allows the easy flow of communication between members is essential. Techniques of delivery include team and peer group teaching, micro-teaching, the use of video-taping, cassette tape recording and other self-teaching devices.

The ability to read and communicate information is part of the cognitive behaviour of a scientist. Uniformity in the use of symbols across the disciplines is advised since it will have the advantage of aiding interrelated teaching by reducing confusion. Teachers should have an introductory course in the teaching of reading with particular reference to science and interrelated subject areas. If part of the education course is to teach individuals to plan and to write curriculum materials for different age groups and abilities then this skill is mandatory.

Training also in the various modes of communication should be incorporated into the strategy. Tutors themselves should demonstrate the potential of the various methods in the teaching-learning situation.

3. Strategies of evaluation

Feedback mechanisms designed primarily for diagnostic rather than achievement purposes would seem to be appropriate for the task of evaluation. Teachers need to develop confidence in their own ability to teach in the new way and to evaluate themselves. They should be willing to make mistakes and be free to experiment with a variety of approaches in the classroom. Far too often the student-teacher perceives the practice teaching as a test situation the purpose of which is the awarding of a grade. The emotional stress involved needs to be reduced if the teacher is to be innovative and acquire self-confidence.

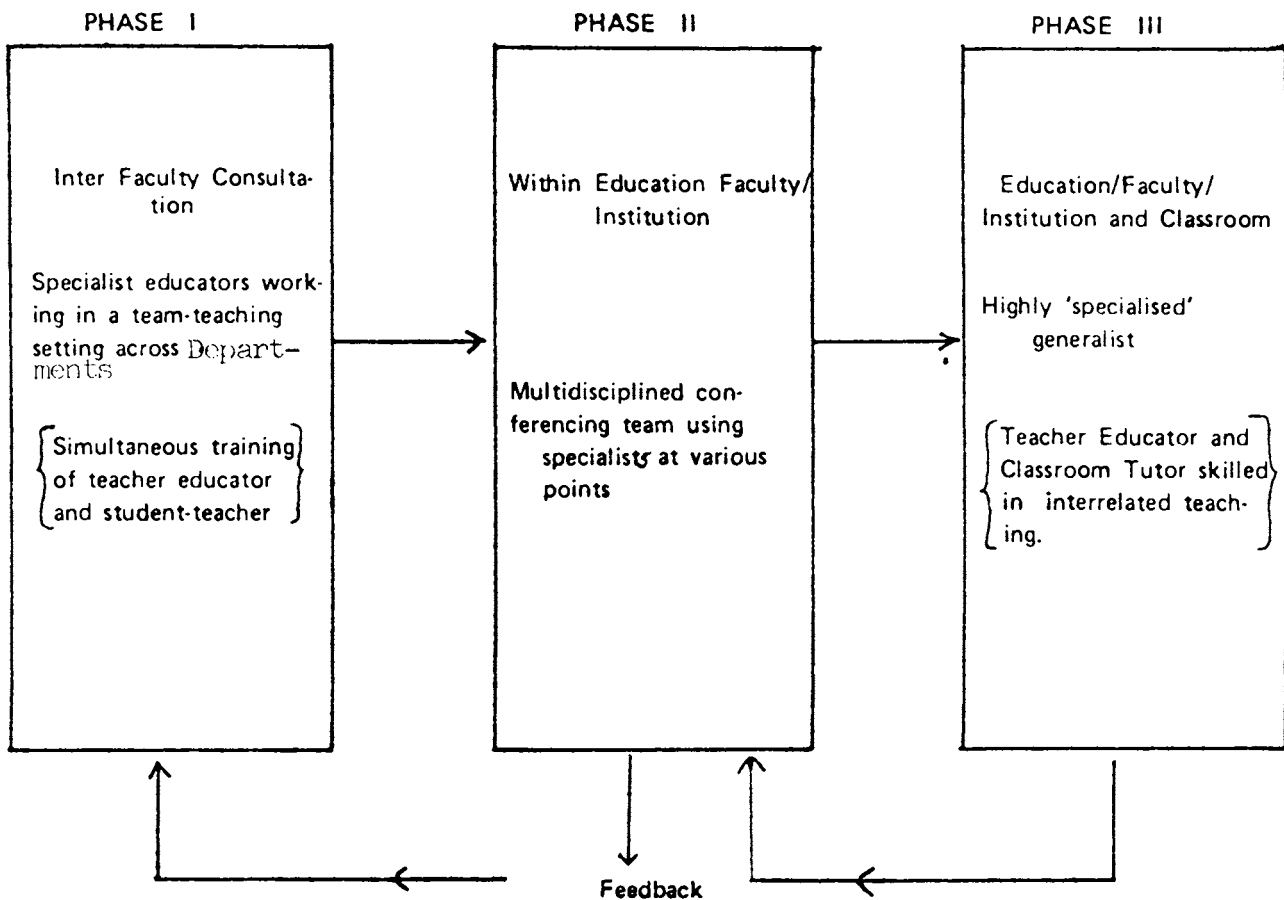
Continuous assessment through written papers, laboratory work, project work including designing curricular units, making equipment from local materials, micro-teaching and peer group assessment are desirable. A credit system using profile ratings is recommended since these have the advantage of highlighting each facet of the multidimensional strengths which the new approach demands.

4. Implementation

Teaching in an interrelated manner will require a reappraisal and restructuring of the educational system. At the secondary level it will mean a radical change in which early specialisation in the disciplines is postponed until the age of 16+ years.

Teachers play a central role in curriculum change. Not only will the proposed change affect pre- and in-service training programmes but a massive retraining of teachers will be necessary if the idea is to survive. Implementation is envisaged in stages or phases as interrelated teaching evolves (see Figure III).

FIGURE III



Without practice and support little can be achieved in the long-term. Guided experience in college at student level and guided experience in schools will be required. Working in college will provide a base in content, a pedagogic model and some sense of security and competence. However, college level work, important though it is, will not be sufficient to bridge the transition into schools. Students need to work with children in classrooms so they can see the mechanisms of classroom management, and experience a working model that will provide an exemplar for further work. The traditional approach whereby one college student is limited to one classroom might not be the best method here; two or more students working together tend to provide a common experience for co-operation, discussion and debate.

It is likely that early experiences in the classroom will be based on work already carried out at college. For many students, the replication of such work will mark the maximum that can be done in schools. However, for the more able students the conception, and development, of 'new' interrelated studies for implementation would seem to be a legitimate goal. Like the agriculturalists we should help people 'grow food' rather than provide 'food'. These proposals suggest that the methodologies at college and school should be similar but should acknowledge the age difference and level of development of the student-teacher.

5. Implications

It is expected that interrelated teaching may well disrupt the educational system. However, the simultaneous training of teacher educator and student-teacher together with the cross-fertilisation provided by team work across Departments should act as stimulants rather than deterrents. Secondary school time-tables will need reorganisation.

Since examinations have a powerful influence on teaching methods it may be possible to capitalise on their influence by modifying them to include a school-based assessment component in the form of projects. Some Examination Boards are already using this mode of assessment.

There will be need for closer links between the tutors of technical and vocational subjects and science and mathematics. At the moment, there is a tendency to view the technical-vocational subjects as inferior to science and mathematics. The areas of study should be seen as complementary. If tutors themselves make a conscious effort to work together as a team it is highly probable that the artificial barriers will begin to break down.

The science teachers' education programme should be extended to include a basic technician's course as well as skills in laboratory management with the accent on the use of indigenous materials and the making of low-cost equipment.

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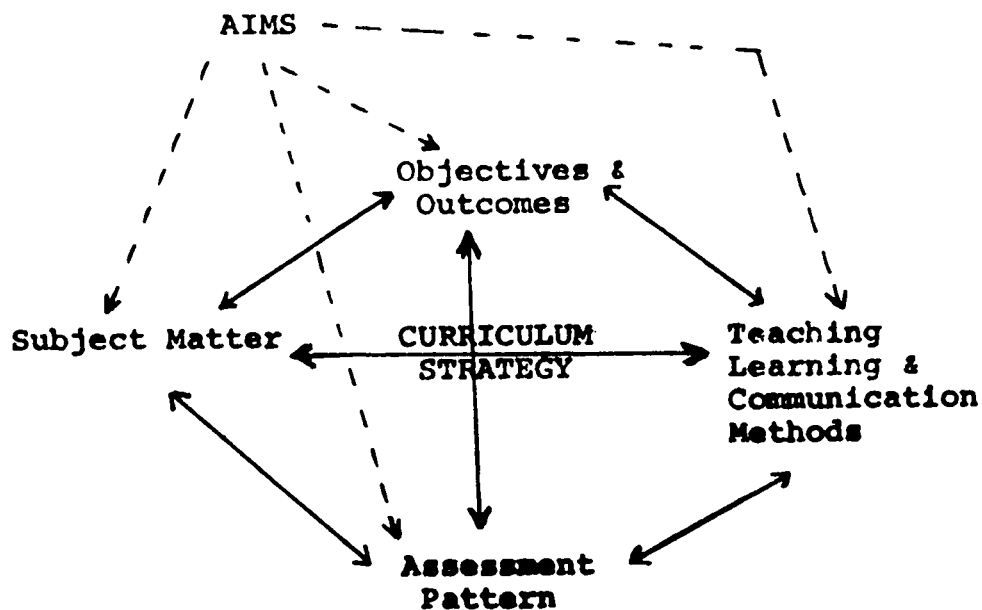
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CHAPTER 7: ASSESSMENT OF STUDENT ACHIEVEMENT IN CURRICULA BASED ON TEACHING SCIENCE, MATHEMATICS, TECHNICAL AND VOCATIONAL SUBJECTS IN AN INTERRELATED WAY
S. T. Bajah

Introduction

Assessment as an educational strategy has been utilised by educators the world over for as long as education has been an organised system in the formal school setting.

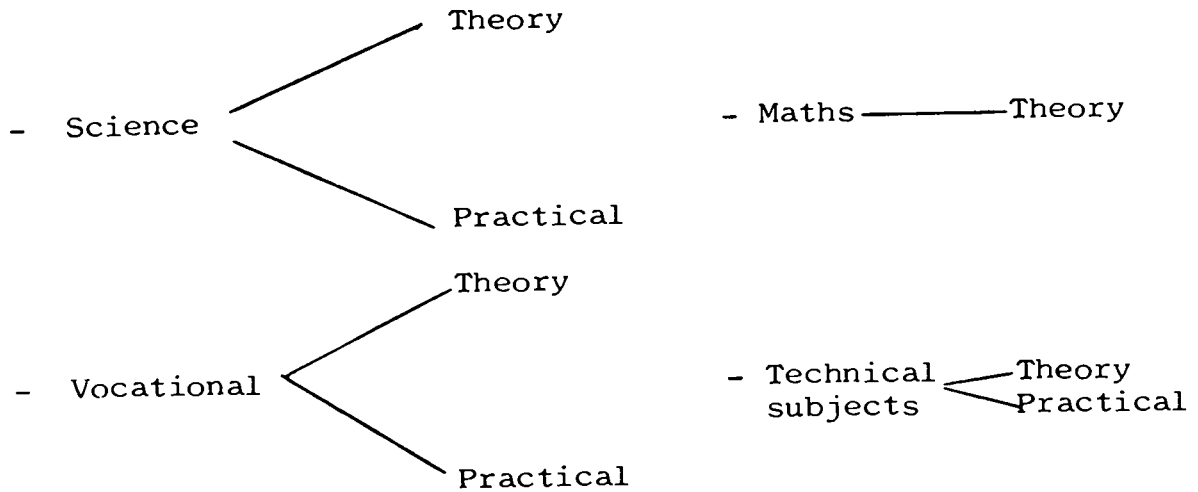
Many curriculum theorists have described the relationship between assessment and what actually goes on in an educational system by developing schemes or models of the curriculum process. One such model, developed by Kerr (1968), depicts subject matter, teaching methods and assessment. Their dynamic interconnections are shown in the diagram:



Assessment in any curriculum strategy provides necessary information in a formative as well as in a summative way with emphasis on diagnostic applications.

Assessment of Science, Mathematics and Technical/Vocational Subjects

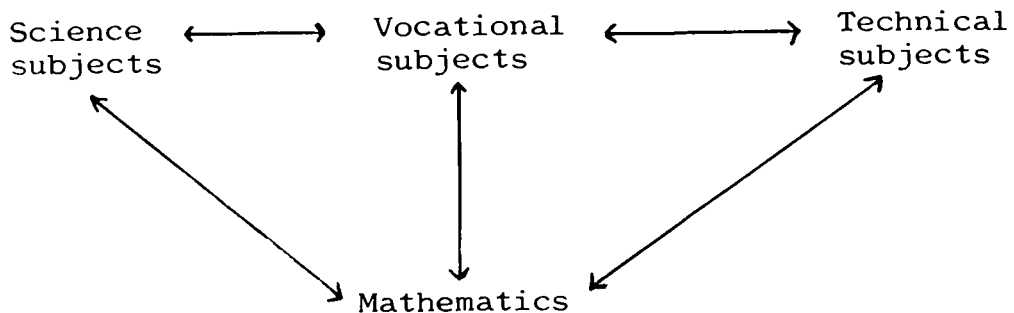
The strategies adopted in the testing of science, mathematics, technical and vocational subjects are simply as follows:



The modality adopted in the assessment of student achievement in all these subjects is the usual paper and pencil testing.

There is no doubt that science, mathematics, vocational and technical subjects are related but emphasis in the inter-relationship was highlighted in some countries only very recently.

Although science is seen as a useful tool in vocational and technical subjects, the role of mathematics is considered to be the most vital link between science, and its application in technical and vocational subjects.



In the assessment of student achievement in these subjects, emphasis has always been placed on outcomes in the cognitive domain. Cognitive assessment of science, mathematics and technical subjects follow a well established universal pattern

fact that we are entering an era when we will be asked to acknowledge the importance of affect, imagination, intuition and attitude as outcomes of science teaching that are at least as important as their cognitive counterparts.

The Use of Tests as Instruments of Assessment

1. Accountability: Tests are used to hold teachers, schools and school systems accountable. Many educational authorities use achievement test scores as a rough gauge of the adequacy of the performance of a teacher, a school or larger administrative unit. The results of a test are then taken to indicate the amount of learning accomplished by the average student in a classroom. With such results, educational authorities decide whether the teaching system is adequate, inferior or superior.

2. Selection: Tests are used to make decisions concerning the placement or selection of individual students. Educational authorities use tests to place individual students in special programmes and classes. Most placement tests constructed by classroom teachers are pretests designed to measure

- (a) whether students possess the prerequisite skills needed to succeed in a course, or
- (b) the extent to which students have already achieved the objectives of a planned instruction.

3. Evaluation and Experimental Projects: Tests are used to evaluate educational innovations and experimental projects. Innovative educational projects have led to a number of reforms in many countries. School systems sponsor experimental projects in schools and seek to evaluate these projects through use of standardised tests. Science and mathematics have received particular attention in this regard. The evaluators have to match the tests to project objectives.

4. Instructional guidance or diagnosis: Tests are used to provide guidance to teachers in the classroom. Instructional guidance tests, also known as formative tests, are given periodically during classroom instruction to monitor the learning progress of students and to provide ongoing feedback to students and teachers. In a way, formative tests are invaluable as diagnostic instruments which teachers adopt for diagnosing student learning difficulties. Diagnostic tests enable teachers to gain detailed information on the particular points of difficulty for each student - information which is necessary if there is to be improvement of performance. Diagnostic tests are not easy to design.

The Why, Who, When and How of Assessment

1. Why assess? This is one aspect of assessment which is steeped in tradition, especially for many Commonwealth countries. The mode of public external examinations became institutionalised in many such countries and the assessment based on how much of the prescribed syllabus had been learned. The onus was on the learner to prove that he or she had learned anything at all. Nevertheless the external examination gives both status and credibility to many educational institutions. It also provides a pointer to the standards of the educational system as a whole.

In science the growing emphasis on practical skills meant the need to devise assessment tests for experimental work. Then came the need to assess project work. Assessment of science fairs and exhibitions of the work of young scientists provided opportunities to evaluate science, mathematics, vocational and technical subjects in an interrelated way.

2. Who should assess? Classroom teachers have an important part to play in assessment of student academic achievement, because the teacher is assumed to have detailed knowledge of the students. It has been claimed that the advantage which a classroom teacher has over the external examiner lies in the knowledge of the work of the student over a wider range of activities and over a longer period of time. However, the external examiner has the advantage of being able to relate the performance of a student to that of others across a country. In order, therefore, for school systems to benefit from both internal and external assessment, it may be desirable to standardise the internal element by external measures. Such standardisation may be accomplished in one or other of three ways:

- by using scaling assessments which are either syllabus-related or independent;
- by moderators visiting schools or looking at samples of the products of school work;
- by using national item banks, from which teachers can draw items or tests to standardise their own assessments.

3. When should assessment be made? Assessment aimed at improvement of performance and guidance must be given at appropriate times and frequency. Diagnostic tests, for instance, require to be administered with greater frequency than other forms of tests. For certification purposes, cumulative assessment has advantages in building up a comprehensive statement about students over their school careers. This however does not negate the use of end-of-course assessment since users of information on students' achievement are also interested in the performance of the individual students at the terminal point.

4. How should assessments be communicated and used? In communicating and using information derived from assessment a distinction must be made between that which is appropriate for use within the school, and other information which can be communicated to the outside world. The limitations identified on the scope of assessments to be transmitted beyond the school are likely to be set, not only by the requirements of fairness, reliability and validity but also by acceptability to the public. To be fair, it was argued, any grades awarded nationally should be comparable; to be reliable, agreed procedures should be carried out efficiently; to be valid the assessment should match the curricular objectives and be pitched at an appropriate level; and to be acceptable, the attributes to be assessed should be agreed among teachers, parents, and the public in general.

Complete transcripts on performance of individual students should form the basis for transmitting academic achievement instead of just the prevalent colourful certificates given in many countries at the present time.

Continuous assessment: Continuous assessment has been advocated by many Governments through their Ministries of Education and other educational authorities. The rationale behind continuous assessment is as follows:

(a) Assessment is an integral part of the teaching process. It is therefore reasonable that teachers should be involved in the final assessment of the students they have taught. The present system whereby the final assessment of students at the end of a particular level of education is carried out through a single examination set by an external body tends to deny teachers the opportunity to participate in the final assessment of their students.

(b) An assessment procedure which takes into account the student's performance throughout the entire schooling is likely to be more valid and more indicative of overall ability than a single examination.

(c) The readiness of teachers to introduce innovations into their teaching is often frustrated by the fact that a final external examination does not take account of innovation.

(d) An important aspect of instruction is the appropriate guidance of students both in their learning and in preparation for careers. A continuous assessment procedure facilitates career guidance.

(e) Teachers also need to assess their own instructional methods from time to time in order to improve performance. Data from continuous assessment can be useful for such self-assessment.

(f) Leakages of examination question papers and other malpractices at external examination or final examination occasions might be obviated if continuous assessment is given due weight in the overall evaluation of students. The pressure on students on the occasion of the single final examination is very great; this pressure will be eased if the assessment is carried out over the entire course.

International Perspective in Assessment

Through the efforts of the International Association for the Evaluation of Educational Achievement (IEA) international comparability studies have been made on student achievement in science and mathematics. A new IEA study on science is currently underway.

No such comparability studies have been carried out in technical and vocational subjects. This may be a reflection of the somewhat inferior attitudes attributed to these subjects and the lack, in some countries, of competent and pedagogically-trained teachers. It is a situation that calls for international co-operation, particularly with the trends towards interrelated studies of science, mathematics, technical and vocational subjects.

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APPENDIX I

HIGHLIGHTS OF THE INTERRELATED MEETINGS OF EXPERTS OF SCIENCE, MATHEMATICS, TECHNICAL AND VOCATIONAL SUBJECTS HELD IN NICOSIA, CYPRUS, MARCH 1982

Twenty-seven specialists from 20 member countries throughout the Commonwealth, (see Appendix II) and observers from UNESCO and CASTME, participated. They met in three groups, which concentrated on: science, mathematics, and technical and vocational education. However, opportunity was provided for a certain amount of interaction between the groups.

The Science Group had as its main working paper "Junior School Science Curriculum: A Commonwealth Approach". In addition it had a background document "Science Education in the Commonwealth", position papers on science and mathematics education from participants' countries, and syllabuses in the relevant subjects from a number of Examination Boards in the Commonwealth. The group agreed that one way of meeting the 8CEC recommendation*, bearing in mind the varied circumstances in which the subject is taught in member countries, was to prepare, as an initial step, a core curriculum linking areas of study in science and mathematics. It then went on to draft a combined programme for the primary and junior secondary levels, i.e. up to the point where the majority of children in most Commonwealth countries leave the school system.

The group identified eleven areas of study to which, in their view, all school pupils should be exposed, both for their personal development and to enable them to contribute to development in their country. These eleven study areas were: senses and measurement; our universe; the human body; food; health and nutrition; ecology; resources (man-made and natural); population; energy uses; technology; and quality of life.

The group recommended that when defining each of these study areas, curriculum designers should prepare a statement justifying its place in the core curriculum. Additional statements should be prepared on (a) the concepts to be acquired, (b) the topics in mathematics and technical and vocational subjects which can be taught in relation to that particular theme, (c) ways of teaching the content so as to bring out interrelationships between the relevant subjects, and (d) the minimum competencies pupils should be expected to achieve.

*see p.1.

The Mathematics Group had as its main working paper "School Mathematics Curriculum: A Commonwealth Approach". Like the Science Group it also had position papers in science and mathematics from countries from where participants had come, together with syllabuses in the relevant subjects from a number of Examination Boards.

The Group deliberated on the role of the school, noting that as an instrument of society to restructure the society, which itself changes from time to time, the school must vary its role along with the changes. It should take into consideration the viewpoints of: (a) parents and children in preparing children for the world of work; (b) the government in producing the right kind of person-power i.e. in preparing children for employment (or unemployment) ; and (c) educators.

It agreed that in designing mathematics curricula one should look for the minimal intersection set (or core) which will prepare the majority of early school leavers to meet the world of employment/unemployment, with additional curriculum blocks (units, modules) for higher-ability students to continue to different stages of schooling. Such a core should emphasise conceptual understanding of topics included in the curriculum. It suggested that curriculum design teams should be composed of interest groups of parents, business and industry users and academics. But, more importantly, teachers ought to be involved in these interest groups in a very significant way so that they may carry the curriculum with them. The group proposed a core curriculum to which all primary school children should be exposed during their five to six years of schooling. In particular, it agreed that the skills of arithmetical operations should not be sacrificed through the use of calculators.

The Technical and Vocational Group had as its working and background documents "Craft, Design and Technology", "The Interrelations of Technology, Science and Mathematics Subjects", "General Technical Education Pilot Project" and examples of technical education syllabuses in the following subjects - woodwork, metal work, technical drawing, electrical, automotive, home economics and agriculture.

The group noted that while traditional methods of teaching craft subjects are used in some countries, in others a practical problem-solving approach had been or was being developed. It agreed that to the extent that the total curriculum is a preparation for work, a concern for vocational preparation is the responsibility of all subjects. It further agreed that the acquisition of craft skills was no longer the sole objective of technical training and that solving practical problems was an important and integral part of workshop practice courses. Noting that it would take a long time for technical education courses based on the problem-solving approach, this group suggested that every effort be made to evolve the latter method because of the considerable benefits to be gained educationally when children are

involved in designing, developing and evaluating practical project work.

Teaching skills required for the successful implementation of curricula based on the problem-solving approach are markedly different from those required by traditional technical subject teachers. The new approach requires the teacher to act as a facilitator and an adviser in order to assist students to learn how to learn, to develop value judgements and skills for searching for resources. The implications for pre-service and in-service teacher training and the need for traditionally trained teachers to have a change of attitude cannot be over-emphasised.

The group also considered the issue of assessment in courses based on a problem-solving approach, noting the possibility of such assessment being accommodated within a formal examination system. Such an approach would include the assessment of intellectual processes as well as craft skills.

Finally, the group attempted to identify the knowledge, skills and attitudes and their most important components relative to a problem-solving type curriculum which are necessary for the generality of school leavers. Skills included investigation, innovation, modelling, realisation, communication, and evaluation. Knowledge included energy, control, materials, and context. Attitudes included resourcefulness, efficiency, reliability, precision, safety, and aesthetic aspects in craftsmanship.

The first interdisciplinary group considered the issue of measurement. It noted that in technical education primary school children are expected to use various instruments correctly and to have a fair understanding of the components; they are not necessarily expected to understand the principles involved. In science education on the other hand children are expected to acquire a wider concept of measurement through a variety of activities and to be encouraged to make inferences.

The group noted some questions that have to be reviewed in formulating guidelines. These include:

- (a) What experiences and activities are to be introduced, at what age and how possible is interrelation between mathematics, science and technical education?
- (b) What strategies are to be adopted?
- (c) What are the implications for the teacher and teacher education?

The second inter-disciplinary group had time to consider the use of materials only in the primary school. It examined materials and resources needed for study and materials and resources as the object of study. In science emphasis is on local materials although a few materials may need to be imported from other countries. In mathematics what is needed is mainly rulers, scales, and weights; many of these can be manufactured locally. Technical subjects require ordinary hand tools for skill development and for the application of science and mathematics.

The third inter-disciplinary group reviewed the areas common to science, mathematics and technology in the teaching about energy. The experts felt that in teaching science, especially at the primary level, the main focus should be on the uses, rather than the concept, of energy. It was suggested that the role of mathematics should be minimal; simple arithmetical applications and graphs could be employed to enhance children's understanding of sources of energy and the need to save energy. In teaching 'energy' in technology at the primary level, the focus should be on control while paying attention also to safety, and to the social, environmental, personal and economic aspects. It was noted, however that while topics may be common to the relevant subjects, in general there is a fundamental difference between scientific and technological methodologies.

The fourth inter-disciplinary group considered 'communication' as being a unifying inter-disciplinary element of the school curriculum in general and in those disciplines of science, mathematics, technical and vocational education. The experts discussed oral and literal, graphics, spatial and numerical skills which they considered fundamental to the teaching and learning of science, mathematics, technical and vocational subjects.

Finally, in a joint meeting of the two groups of experts, it was agreed that:

1. The education of teachers is crucial to the implementation of the proposed guidelines which demand an understanding of the relationships between science, mathematics and technology.
2. A problem-solving approach should be used so that the interrelationships are clearly seen and used as an integrating factor.
3. Any curricula designed should make use of locally available materials so as to keep educational costs at a minimum.

APPENDIX II

DIRECTORY OF PARTICIPANTS AT THE INTERRELATED MEETINGS

(Held in Nicosia, Cyprus, March 1982)

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APPENDIX III

PROVISIONAL SPECIALIST CONFERENCE AGENDA

1. Interrelation of Science, Mathematics, Technical and Vocational Curricula

- (a) Examining Commonwealth experience in the development of school curricula based on innovative approaches to the interrelation of science, mathematics, technical and vocational subjects and their interaction with the world of work.
- (b) Formulating guidelines for the design of inter-related science, mathematics, technical and vocational subjects.
- (c) Recommending practical ways to produce and implement interrelated curricula and arrangements to improve interaction between school and the world of work.

2. Teacher Education Systems and Interrelated Curricula

- (a) Examining teaching competencies necessary to implement interrelated science, mathematics, technical and vocational curricula.
- (b) Formulating teacher education strategies to achieve and maintain competence for teaching interrelated science, mathematics, technical and vocational curricula.

3. Communication in Science, Mathematics, Technical and Vocational Subjects

- (a) Examining Commonwealth experience in linguistic and graphical/pictorial difficulties which are encountered in teaching and learning of science, mathematics, technical and vocational subjects.
- (b) Recommending practical ways to overcome linguistic and graphical/pictorial teaching and learning difficulties in interrelated curricula.

4. Provision of Resources for Science, Mathematics, Technical and Vocational Education

- (a) Formulating proposals to increase local self-reliance in the provision of resources including laboratory, workshop and physical facilities used in the teaching of science, mathematics, technical and vocational subjects.
- (b) Identifying special requirements for the assessment of performance in interrelated science, mathematics, technical and vocational curricula.
- (c) Formulating guidelines on suitable methods of assessment related to non-traditional experimental work, activities linked with the world of work and desired student attitudes in studying interrelated curricula.

5. Bilateral and Multilateral Co-operation

- (a) Identifying ways of utilising existing patterns of bilateral and multilateral co-operation to establish and sustain the interrelation of science, mathematics, technical and vocational curricula.
- (b) Formulating proposals for innovative programmes of bilateral and multilateral co-operation to improve and increase assistance to governments in their efforts to develop interrelated school curricula in science, mathematics, technical and vocational subjects.

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