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 ESL* 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 Na+(aq)= NaCl(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 ambiquity (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 diagramatic 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'; thev 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 (isometic, 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.

<u>Case-Study P1: Canada</u>. 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 schoolboys 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 is 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; Michelmore, 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.

References

Alonge, E.l. An Investigation of the Effects of Language on the Understanding of Spatial Relationships by Nigerian Secondary School Children. Unpublished M.Sc. dissertation (University of East Anglia, Norwich, 1977).

Ausburn, F. B. and Ausburn, L. J. Perception, Imagery and Education in Developing Countries: Report No. 17, Mathematics Education Centre (University of Technology, Papua New Guinea, 1981).

Ausburn, F. B. and Ausburn, L. J. Cognitive Styles and Visual Analysis Skills in Papua New Guinea Students: Report No. 21, Mathematics Education Centre (University of Technology, Papua New Guinea, 1982).

Austin, J. L. and Howson, A. G. 'Language and mathematical education', in Educational Studies in Mathematics, Vol. 10, No.2, 1979, pp. 161-197. Reprinted by the School Mathematics Project (London, 1980).

Berry, J. W. 'Temne and Eskimo perceptual skills', in International Journal of Psychology, Vol. 1, 1966, pp. 207-229.

Berry J. W. 'Ecological and cultural factors in spatial perceptual development', in Canadian Journal of Behavioural Science, Vol. 3, 1971, pp. 324-336.

Berry, J. W. and Annis, R. C. 'Ecology culture and psychological differentiation' in International Journal of Psychology, Vol. 9, 1974, pp. 173-194.

Bishop, A. J. 'The use of structural apparatus and spatial ability: a possible relationship', in Research in Education, Vol. 9, 1973, pp. 43-49.

Bishop, A. J. Developing Spatial Abilities: Report No. 4, Mathematics Education Centre (University of Technology, Papua New Guinea, 1977).

Bishop, A. J. Spatial Abilities in a Papua New Guinea Context: Report No. 2, Mathematics Education Centre (University of Technology, Papua New Guinea, 1978).

Bishop, A. J. and Tombs, D. Mathart Workshop (The British Council, London, 1982).

Bruner, J. S. 'Language as an instrument of thought', in A. Davies (ed.) Problems of Language and Learning (Social Science Research Council, London: Heinemann, 1975).

CASTME. Language and the Teaching of Science and Mathematics with special reference to Africa: report of a CASTME Regional Workshop, Accra, Ghana (CASTME, The Commonwealth Secretariat, London, 1975).

Chimuka, S. S. and Zulu, R. S. The Medium of Instruction in Primary Schools in Zambia. (Division of Science, Technical and Vocational Education, UNESCO, Paris, 1974).

Clarkson, P. C. 'Students' use of diagrams and visuality in mathematics', in Research in Mathematics Education in Papua New Guinea, 1981 (Mathematics Education Centre, University of Technology, Papua New Guinea, 1981, pp. 1-20).

Clarkson, P. C. Mathematics Learning in P.N.G. National High Schools: the Analytic-Visual Variable: Report No. 22, Mathematics Education Centre (University of Technology, Papua New Guinea, 1982).

Coppen, H. Visual Perception: a review of the literature relating to studies relevant to the development of teaching materials in the Commonwealth (Commonwealth Secretariat, London, 1970).

Dasen, P. R. 'Concrete operational development in three cultures', in Journal of Cross-Cultural Psychology, Vol. 6, 1975, pp. 156-172.

Dawe, L. C. S. The Influence of a Bilingual Child's First Language Competence on Reasoning in Mathematics. Unpublished Ph.D. dissertation (University of Cambridge, 1982).

Dawe, L. C. S. 'Bilingualism and mathematical reasoning in English as a second language', in Educational Studies in Mathematics (in press, 1983).

Department of Language and Social Science, The Language of Mathematics, Parts I and II. University of Technology, Papua New Guinea, 1976.

Evans, G. S. Four Cues imparting Depth to Line Drawings of Molecular Models: an African (Nigerian) Study. Unpublished M.Sc. dissertation (University of East Anglia, Norwich, 1974).

Evans, G. S. and Seddon, G. M. 'Responsiveness of Nigerian students to pictorial depth cues', in Educational Communication and Technology Journal, Vol. 26, No. 4, 1978, pp. 313-320.

Ghuman, P. A. S. The Cultural Context of Thinking. A comparative study of Punjabi and English boys. National Foundation for Educational Research (Slough, 1975).

Giles, G. 'Geometry for all', in Mathematics Teaching No. 100, September 1982, pp. 30-37.

Glennon, V. J. Neuropsychology and the Instructional Psychology of Mathematics. The first annual J. W. Wilson Memorial Address, Seventh Annual Conference of the Research Council for Diagnostic and Prescriptive Mathematics; Vancouver, B.C., Canada. Kent, Ohio: RDPM, 1980.

Harris, P. J. Mathematics and Measurement in tribal Aboriginal Communities. (Curriculum Development Centre, Government Printer, Canberra, Australia, 1980).

Haynes, J. Educational Assessment of Immigrant Pupils. National Foundation for Educational Research (Slough, 1971).

Holmes, A. C. A Study of Understanding of Visual Symbols in Kenya, OVAC Publication No. 10 (Overseas Visual Aids Centre, London, 1966).

Jones, P. (ed.). Language level of Form A students in Lesotho, in Language in the Mathematics and Science Lesson, Part 1: Department of Science Education, National University of Lesotho (Roma, 1980).

Jones, P. L. Mathematical Language and the Learning of Mathematics in Papua New Guinea: Report No. 16, Mathematics Education Centre (University of Technology, Papua New Guinea, 1981a).

Mitchelmore, M. C. Solid Representation Test Manual, unpublished report (Ministry of Education, Kingston, Jamaica, 1975).

Mitchelmore, M. C. 'Three-dimensional geometrical drawing in three cultures', in Educational Studies in Mathematics, Vol. 11, No. 2, 1980, pp. 205-216.

Mitchelmore, M. C. 'Cross-cultural research on concepts of space and geometry', in J. L. Martin (ed.) Space and Geometry (ERIC/SMEAC, Columbus, Ohio, U.S.A., 1976, pp. 143-184).

National University of Lesotho. Language in the Mathematics and Science Lesson, Report of a Workshop, January 1980, Parts 1 and 2. Department of Science Education (Roma, 1980).

National University of Lesotho. Report on the Second Workshop on Language in the Mathematics and Science Lesson. Department of Science Education (Roma, 1981a).

National University of Lesotho. Teachers' Resource Books: No.1. Language for Mathematics and Science; No. 2. Language in Integrated Science; No. 3. Language in Mathematics Lessons. Department of Science Education (Roma, 1981b).

Nicholson, J. R. An explanatory study into the Perception of Spatial Relationships in Diagrams of Framework Structures by Nigerian University Science Students and Secondary School Pupils. Unpublished M.Sc. dissertation (University of East Anglia, Norwich, 1974).

Nicholson, J. R. and Seddon, G. M. 'The Influence of secondary depth cues on the understanding of Nigerian schoolboys of spatial relationships in pictures', in British Journal of Psychology, 68, 1977a, pp. 327-333.

Nicholson, J. R. Pictorial Shape. Unpublished Ph.D. thesis (University of East Anglia, Norwich, 1976).

Nicholson, J. R. and Seddon, G. M. 'The understanding of pictorial spatial relationships by Nigerian secondary school students', in Journal of Cross-Cultural Psychology, Vol. 8, No. 4, 1977b, pp. 381-400.

Nicholson, J. R., Seddon, G. M. and Worsnop, J. 'Teaching the understanding of pictcrial spatial relationships to Nigerian secondary school students', in Journal of Cross-Cultural Psychology, Vol. 8, No. 4, 1977, pp. 401-414.

Olson, D. R. 'On the relations between spatial and linguistic processes', in J. Eliot and N. J. Salkind (eds.). Children's Spatial Development (Thomas, Springfield, Illinois, U.S.A., 1975).

Purcell, J. A Test of Spatial Ability. Science Education Department, University of Warwick (Coventry, 1983b).

Purcell, J. Scientific and Spatial Abilities. Science Education Department, University of Warwick (Coventry, 1983a).

Reed, M. 'Language and Mathematics at tertiary level', in Research in Mathematics Education in Papua New Guinea, 1981 (Mathematics Education Centre, University of Technology, Papua New Guinea, 1981, pp. 80-96).

Reed, M. and Wainman, H. 'Language competence in Mathematics', in International Journal of Mathematical Education in Science and Technology, Vol. 9, No. 1, 1978, pp. 31-33.

Jones, P. L. Learning Mathematics in a Second Language: Report No. 19, Mathematics Education Centre (University of Technology, Papua New Guinea, 1981b).

Jones, P. L. 'Solving word problems in a second language and reading proficiency', in Research in Mathematics Education in Papua New Guinea, 1981 (Mathematics Education Centre, University of Technology, Papua New Guinea, 1981c, pp. 58-74).

Kleinfeld, J. S. 'Intellectual strengths in culturally different groups: an Eskimo illustration', in Review of Educational Research, Vol. 43, 1973, 341-359.

Krutetskii, V. A. The psychology of Mathematical Abilities in School Children (trans.). Chicago University Press, Chicago and London, 1976.

Lean, G. A. An Investigation of Spatial Ability among Papua New Guinean Students: Report No. 9, Mathematics Education Centre (University of Technology, Papua New Guinea, 1980).

Lean, G. A. 'The rotation and development of surfaces: a study of a Piagetian spatial task with Papua New Guinea secondary school pupils', in Research in Mathematics Education in Papua New Guinea, 1982. (Mathematics Education Centre, University of Technology, Papua New Guinea, 1982, pp. 117-159).

Lean, G. A. and Clements, M. A. Spatial Ability, Visual Imagery and Mathematical performance: Report No. 10, Mathematics Education Centre, (University of Technology, Papua New Guinea, 1980). Also published in Educational Studies in Mathematics, Vol. 12, No. 3, pp. 267-299 (1981).

Lewis, D. 'Route finding by desert Aborigines in Australia', in The Journal of Navigation, Vol. 29, No. 1, January 1976, pp. 21-39.

Little, A. 'performance of children from ethnic minority backgrounds in primary schools', in Oxford Review of Education, Vol. 1

MacArthur, R. S. 'Sex differences in field dependence for the Eskimo: replication of Berry's findings', in International Journal of Psychology, Vol. 2, 1967, pp. 139-140.

MacArthur, R. S. 'Some ability patterns: Central Eskimos and Nsenga Africans', in International Journal of Psychology, Vol. 8, 1973, pp. 239-247.

MacArthur, R. S. 'Differential ability patterns', in J. W. Berry and W. J. Lonner (eds.), Applied Cross-Cultural Psychology: selected papers from the second international conference of the IACCP (Amsterdam, Holland: Swets and Zeitlinger, 1975).

McFie, J. and Thompson, J. A. 'Intellectual abilities of immigrant children', in British Journal of Educational Psychology, Vol. 40, No. 3, pp. 348-351 (1970).

Meek, C. and Feril, N. A Pilot Study into the Level of Comprehension of some Words taken from the Papua New Guinea Community School Mathematics Syllabus: Report No. 3, Mathematics Education Centre (University of Technology, Papua New Guinea, 1978).

Mitchelmore, M. C. 'Spatial ability and three-dimensional drawing', in Magazine of the Mathematical Association of Jamaica, Vol. 5, No. 2, 1973, p. 15.

Ross, A. R. The Remedial Treatment of Problems of Depth Perception in Diagrams: A Nigerian study. Unpublished M.Sc. dissertation (University of East Anglia, Norwich, 1977).

Saunderson, A. The effect of a special training programme on spatial ability test performance', in New Guinea Psychologist, 1973, Vol. 5, pp. 15-23.

Shaw, B. Visual Symbols Survey: a report on the Recognition of Drawings in Kenya (Overseas Visual Aids Centre, London, 1969).

Sinha, D. K. and Das, A. K. 'A note on interaction between language and mathematics in a mathematical context', in International Journal of Mathematical Education in Science and Technology, Vol. 13, No. 4, 1982, pp. 401-404.

Soni, R. B. The New Experiment on the Numericals from 1 to 100 in Gujerat. Unpublished CASTME paper, the Commonwealth Secretariat, (London, 1982).

Strevens, P. 'Problems of learning and teaching science through a foreign language', in Studies in Science Education, Vol. 3, 1976, pp. 55-68.

Strevens, P. 'The language of instruction and the formation of scientific concepts', in Science and Education in the Developing States, P. and H. Gillon (eds.), Praeger, New York, 1971.

Towse, P. J. An Evaluation of the Lesotho Integrated Science Improvement Programme, with particular reference to the effects of this course on attitudes to, and an understanding of, science. Unpublished M.Ed. thesis (University of Hull, 1977).

UNESCO. Interactions Between Linguistics and Mathematical Education. UNESCO, Paris, 1974.

Vernon, P. E. 'Educational and intellectual development among Canadian Indians and Eskimos', in Educational Review, Vol. 18, 1966, pp. 79-91.

Wilson, B. J. Cultural Contexts of Science and Mathematics Education: a bibiographic guide (Centre for Studies in Science Education, University of Leeds, 1981a).

Wilson, B. J. 'Language and mathematics education: an international perspective', in Research in Mathematics Education in Papua New Guinea, 1981b, pp. 154-166).

Worsnop, J. An Investigation into the Possible Remedial Effect of Stereoscopic Projection in the field of Pictorial Depth Perception. Unpublished M.Sc. dissertation (University of East Anglia, Norwich, 1975).