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Author(s)	A. B. Elliot
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## Science in English

If we think of ourselves – human beings – as one species in the huge collection of different species of living things, we can observe that we are in some ways similar to other organisms, other animals, other mammals and other primates . . . but in some ways we are strikingly different from these other living organisms. And one of the most important ways in which we are different is that we have a highly developed and efficient means of communication between individuals. This difference may be related (although we cannot say which is cause and which is effect) to the long period of immaturity in human beings, where the young are born helpless and then spend anything from twelve to twenty years in “childhood”, during which time they learn and acquire skills and understanding before becoming sexually mature and capable of supporting themselves.

During this period of childhood, through which every adult human being must first pass, the individual progresses from the communicative ability of the newborn infant, which is mediated mainly through touch and perhaps sound, to the extremely elaborate communicative ability of the mature and well-educated young adult, which is mediated mainly through language. When this adult stage is reached, the individual has available to him the entire body of human experience as recorded in recent millenia, and also the total contemporary range of human experience and expectation. Also, in relation to the present and the future it is open to the individual to contribute to and to influence this human experience and expectation by communicating with his contemporaries and with future generations. “No man is an island” – he is a social animal.

### The Monolingual Child

We might look at the interactions between an individual and his society, and if, as in so many parts of the world, his society is homogeneous and monolingual we might see the relationships shown in diagram 1. Here we look at one individual

human being living in the present. In his life, thinking and activities, there are diachronic interactions in time (contributions from the past and contributions to the future), and there are synchronic interactions with contemporary human beings (both directly and indirectly, and both as donor and as recipient).

During the period of childhood, the individual who grows up in a homogeneous community is simultaneously acquiring the *means* of communication (language expressed through the modes of hearing, speaking, reading and writing) and the *substance* of the accumulated wisdom of the past and the present (the knowledge and habits of his society expressed in its culture, ideals and skills). This wisdom can be communicated increasingly efficiently as the growing child becomes better able to use the spoken language (hearing and speaking) and the written language (reading and writing); and increasingly the child receives communication *from* others. But even in earliest childhood the individual contributes also by communicating *to* his fellow human beings, and ultimately as an adult he will contribute to other human beings, both present and future. His use of language will be the means by which his thought, understanding and innovative proposals can be communicated to others, but it is also of more fundamental importance in that through language he will be stimulated to better thought, understanding and proposals by communicative interaction with these activities in other people. This is particularly obvious in the field of science where the thinkers in the front line of advance are so mutually influential that apical discoveries and theories are often made simultaneously by different workers and must be regarded as products of the total climate of thought of all the workers in the field.

This web of communication which enables man – the social animal – to achieve so much is chopped into sectors by the fact that the world has so many different languages. The adult who has matured in one language community can com-

Diagram 1 MONOLINGUAL SITUATION

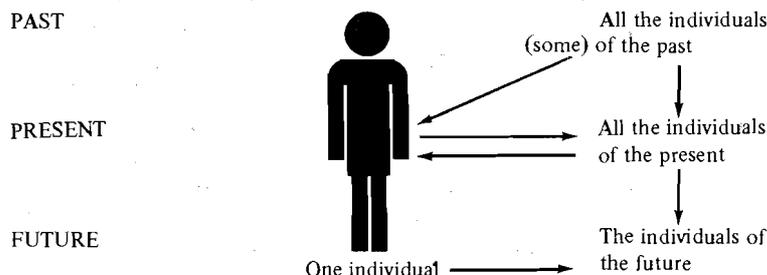
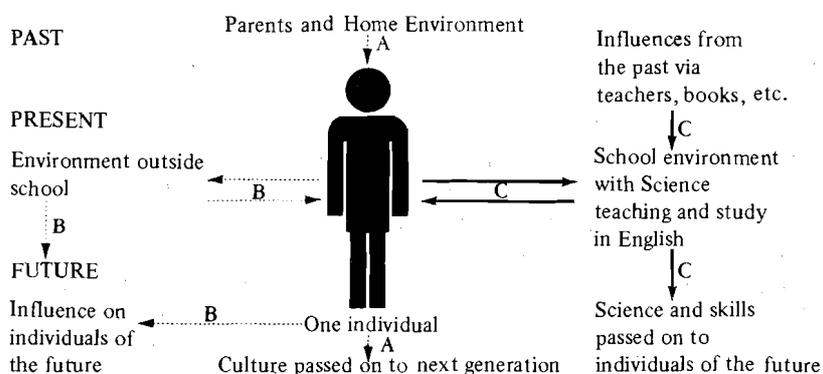


Diagram 2 SINGAPORE SITUATION



municate only with difficulty and through translation with individuals and communities using other languages.

Our concern is with Singapore, where the situation is far from homogeneous, and where two long-established languages — English and Chinese — meet and interact.

It is widely accepted that the normal psychological development of an individual proceeds best if there is close physical and communicative contact with parents, and through the parental language with the cultural heritage. This happens in the home. If this development proceeds normally the individual can then go on from a position of security to investigate the wider world, to meet contemporaries and peers (whose heritage need not be identical), and to acquire further knowledge and understanding. This happens in the world outside the home, and especially in the school.

### The Multilingual Child

We can now reconstruct our diagram to show the special Singapore situation as it applies to the majority of our children — those who grow

up in a home environment where some language other than English is used.

The diagram (Diagram 2) now begins to look rather complicated. And if all the possibilities, permutations and combinations of language were included it would become *very* complicated. Most children in Singapore are exposed in the formative pre-school and primary school years to three, and often four, languages.

1. Language A in the diagram may be any one (or two) of the Singapore languages.

2. Language B is commonly Hokkien, but may be Mandarin, Malay, etc. We must include too that very mixed argot which is commonly used by children playing together; it has a base of English but is much modified by the other Singapore languages.

3. Language C is English. It must necessarily be English of an internationally understandable variety. It is used by children and adults for studying science, for working in technical and technological situations, and for the planning and execution of all scientific aspects of national development. It is used also in other situations, but it is this use of English for science which is our topic at the moment.

We should note here that this use of English is a decision conditioned by our economic situation, and not a decision enforced by the quality or content of any of the languages in question. The potential exists in all human languages to be the media used for the communication and development of science. For us, the necessity of using English arises from the fact of our economic dependence on trade and industry, and the need for us to have access to and to communicate with people in other countries who use English in the fields of science, technology and industry.

### Problems Inherent in Bilingualism

In the complexities of this situation the mere decision to use English for science will not enable us to surmount the difficulties of operating within the framework of Diagram 2. We will need to do some hard thinking about the means we can adopt to ensure that all the channels marked "C" on the diagram are open channels along which truth can be freely communicated from person to person without confusion or misunderstanding. In other connections Singaporeans have often been reminded that "We never get anything for nothing." And this is as true in relation to language as in relation to any other commodity. The ability to use more than one language is an ability which is achieved only at great cost in time and effort. It usually also imposes some limitation on the extent of the lexis and the number of registers available to the multilingual person in each language.

It is easiest for a person to acquire two languages if both are learned during childhood in the period from birth up to about the age of five, during which time the inherent human ability to accept and use language is most manifest. If, as is suggested by psychologists applying information theory, the human ability to identify a language stimulus is a process of successive classification using a binary system, then when two languages are present each identifying process has added to it the preliminary decision as to which language is being used. This need add very little time (or trouble) to the process of using language. On this view it is understandable that the young child can cope with two languages at the time when language is being acquired. It can be observed that the ease with which the young child switches from one language to another is associated with the recognition of the environment and contexts in which each language is appropriate. It may be a source of amazement to the parents that the child does not confuse the languages, but in fact the child's deci-

sion is probably simply situationally determined. The language which is used is a response to a person (e.g. grandmother), a situation (e.g. school), an auditory stimulus (the language in which the child has been addressed), etc.

But there is another consideration to be taken into account. At the time (usually about the age of five or six) when the child has accepted and learned the use of the language (or languages) of his environment, he has an ability to *produce* statements using the framework of the syntax of each language. He will later extend his syntactical understanding, but he does possess at this time many of the basic grammatical patterns. He can accept with understanding statements which he has never heard before provided they are grammatically presented. But he still operates with a limited vocabulary. The fluency and accuracy with which he will later, as an adult, express his thought and receive ideas from others will depend not only on the communication being couched in correct grammatical form but also on vocabulary – the numerous and different words which he can draw on for his own expression, and which he can comprehend when offered by other people. We must ask ourselves whether the truly bilingual adult has at his command twice as many words as his monolingual friend, or whether, since in the nature of things his bilingual situation will have led to each lexical item having had only half as much reinforcement, he will tend to forget (in both languages) a proportion of the words which he hears and uses less frequently. If this is so, then his capacity to communicate in each language will be reduced by the fact of his ability to use two languages rather than one. We may take the view that some loss of *quantity* in each language is acceptable in order that communication, using a slightly restricted vocabulary, may be possible in *both* languages. But we should not delude ourselves that we can ever get "something for nothing" – command of a second language to such an extent that the total vocabulary is double what would have been available had the same number of years been spent in using only one language.

In real life, of course, we cannot make an experiment on any one person. But we do have many individuals whom we can observe who have become, to varying degrees, bilingual. What we usually see is that the bilingual person tends to "specialise" in his use of language. He may have one language which he uses in talking with his parents, another language when he talks to his children, and perhaps another language still which he uses when he is at work. The professional man

may often be observed to discuss his professional activities in one language, and his cultural history in another. While such a dichotomy may be purely pragmatic, it must inevitably interfere with full interaction between the two aspects of his life. His situation has been likened by some writers to that of a tree whose branches have been cut off from its roots. There is some cause for concern if this is indeed happening.

The highest level of organisation of language is discourse — the logical and allusive presentation of ideas in sequence. It is a moot point whether the ability to organise linguistic discourse is a prerequisite or a concomitant of intelligent thinking. The question of whether bilingualism affects the ability to order discourse is, on either ground, an important one. It has been suggested by linguists that “vocabularies canalise thought”, and that language must be accepted in its role as “a mediator of human behaviour”. It might be that bilingualism bestows benefits by opening up new canals with new mediators of behaviour, so that there would be gain here to offset some of the disadvantages which are so obvious. But research still needs to be done, and we do not yet know the answer to this nor to many other related questions.

We can, however, get down to ground level again, and look at some of the problems which are in practice associated with the teaching of science in English in Singapore.

### **The Need to Speak Before Writing**

When, in some countries, it has been considered necessary for scientists to be able to study their subject at an advanced level in English, it has sometimes been suggested, and even put into practice, that they should learn to use English only in the modes of reading and writing, and without learning to hear and speak. This is indeed possible. We have all heard the amusing stories of the “Chinese scholars” from Europe who have learned to read Chinese, but cannot understand one word of the spoken language. It must be a laborious and therefore undesirable experience. In any case, since English is a “phonetic” language, albeit imperfectly so, there can be little question that it is wise for us to base our use of English first on an ability to hear and speak and then later on an ability to use the written language. It might perhaps be argued that we should place more emphasis on the spoken word in our earlier studies of science, since there are two advantages attached to this — a saving of time, and an avoidance of some later difficulties, mispronunciations and

confusions. A thorough familiarity with the two words “daily” and “diary” before they are seen in print will lessen the confusion between them. This argument will hold only if the speech to which young children are being exposed is reasonably correct. A speech error which comes to mind is the tendency (following the open syllables of the Chinese) for Singapore speakers of English to leave out (or perhaps to leave unaspirated) the consonantal endings of words. This leads to “minus” being pronounced as “minu’”, “freeze” as “free’”, etc. Dependence on speech as an introduction to English can be effective only if teachers are prepared to be meticulous in avoiding such errors as this in their own speech. If we look at our two diagrams, and consider the problems inherent in teaching science and technology in English to the student depicted in the second diagram, we can imagine that the nature of the difficulties experienced will vary. At primary level the pupil lacks chiefly the basic framework of the English language; at tertiary level his difficulty is more with the plethora of long technical words which he has to comprehend. Let us consider, since it will have a bearing on both extremes, the situation of the pupil entering secondary school in the context of the second diagram. He has a home language and perhaps one or more other languages in which he has been accustomed to operate his daily activities. In English he has a small vocabulary, and a relatively small ability to discuss life’s experiences. There are problems which will face both him and his teacher.

### **Extrapolating from an Existent (or Non-Existent) Base**

A good teacher, given a monolingual situation, would naturally base his teaching on the foundation of the knowledge which his pupil brings with him into the classroom, extrapolating from the experiences of daily life to the generalisations of science. If he tries to apply this method in teaching the bilingual or trilingual child, he will immediately face difficulties in that the child has the experience of life but lacks the English words to describe his experience. Linguistically the teacher is in danger of extrapolating from a non-existent base. This becomes very obvious if textbooks based on a typical English child’s experience are used. Such books, for example, commonly introduce the mathematical concept of sets by talking about a team of football players (which a Singapore child would understand) and a flock of sheep (which a Singapore child would probably

not understand). The idea of the flock of sheep which does help the European child to understand the nature of a set, is nothing but a hindrance and even a factor inducing despair to the Singapore child. If we suggest that such examples should be omitted, this is not to say that no information about the foreign environment should be taught. The tropical child needs to be told about snow, just as the child in northern zones needs to be told about tropical islands. The argument is that the basic examples should be drawn from the child's own experience, and should be examples which he is capable of describing in English words. A pleasing example of just such a use of the Singapore-based example was provided by the Singapore teacher who explained to his pupils that distilled water could be seen inside the lid of the rice cooker.

### The Vocabulary of Textbook Instruction

The very language used in instruction in the textbook may present difficulty, and this is particularly so with imperatives (commands) where the child reader of the book is told to "consider", "compare", "evaluate", etc. Lacking a clear understanding of what each command really means he hopefully "does something", and at the same time he begins to develop the habit of sliding over the difficult word and extracting only an imprecise meaning, thus becoming careless instead of meticulous in his reading and thinking. This is a problem which can be tackled on the individual level by preliminary (and it must be admitted rather time-consuming) preparation. A more general solution might be sought by controlling the extent of the vocabulary used. For example, "pick", "choose", "select", and "identify" are sufficiently close in their meaning for us to consider deliberately using one and eliminating the other three from lower secondary texts.

### The Framework of Logical Discourse

Even more important than the "command" words of textbook instruction are the words which form the logical framework of English — the words which connect phrases and clauses and which lead the reader with expectation from one item of the discourse to the next. At their simplest these are the little conjunctive words such as "and", "or", "but", etc. Those with logical implications and more complex functions which connect the thought of one discourse item to the next are more difficult to explain and to use; such words are "if", "as", "so", "because", "since", "although", "however", etc. A monolingual child enters secondary school with a good stock of these words, for he has heard them used since infancy: "If you do that, it will break!", "You didn't eat your meat. So you can't have any cake!", etc. The multilingual Singapore child may of course have heard and become accustomed to quite a large list of these words. But it is equally likely that he will have only a very small number of them which he can use normally and easily — perhaps less than ten of them.

But the discourse of science depends absolutely upon these words. Considering only those connectives which relate entire sentences to each other, it has been found (Winter, 1971) that in a large corpus of scientific writing, there was on average one of these connectives for every eight sentences. So in every eight sentences there were two sentences which were logically related to each other by a word of this type. Analysis showed that if the connective words were classified, then the connectives which denoted logical sequence were the most numerous group, and provided about one third of all the examples. The next most frequent — the connectives signifying contrast — provided about one quarter of all the examples. The other types of connectives followed in the order shown below:

Types of Connective	Examples
Logical sequence:	thus, therefore, yet, hence, so, etc.
Contrast:	however, in fact, yet, nevertheless, etc.
Doubt:	probably, perhaps, possibly, etc.
Addition (non-contrastive):	moreover, similarly, also, etc.
Expansion:	for example, especially, etc.

The two words which head the list are of pre-eminent importance. In the study quoted "thus" accounted for 11% of the total use of such connectives, and "therefore" accounted for 9%. Although the remaining words of this type are used with less frequency they each supply a significant modicum of meaning. If we exclude these words from our writing we immediately find ourselves limited to simple statements of fact. Any attempt to explain how one happening is related to another, to make comparisons, to try to match things, to project thought into the past or the future, requires the use of these words. The bilingual or multilingual Singapore child entering secondary school is faced with textbooks written in English which use these words liberally. The scientist's nature is to think and write logically, and to connect his discourse with such words. In one lower secondary textbook examined – a textbook which appeared to be simply and well written – there were more than sixty different such connective words used.

If the pupil does not understand these words he is not worried. He does not even stop to wonder. He simply takes hold of the two factual items offered to him, and pays no more attention to the connection between them. Any reader can try the experiment for himself. Simply take a paragraph of reasoned discourse and strike out all the connecting words of the type shown above. The passage will still appear sensible. It will make a series of statements. But looking at the words crossed out the reader should be able to see that what has been lost in removing them is the scientific meaning of the passage and the mutual interdependence of the statements in it. Here is an example: "As the angle of incidence increases so the emergent beam increases in strength." Now eliminate "as" and "so". The passage still reads sensibly: "The angle of incidence increases. The emergent beam increases in strength." But without the connective words the concept of the relationship and the information that the two changes happen "in parallel" has been lost.

If this problem is tackled by attempting to improve pupil understanding, it must be acknowledged that these words are peculiarly difficult to teach, and full understanding normally comes only with frequent use. If the problem is tackled by simplification of the format in which science is presented, the teacher and the textbook writer face uncomfortable decisions in having to sacrifice some scientific exactitude in order to achieve pupil understanding.

## Vocabulary of Science

The various sciences have each generated their own huge vocabulary of nouns, adjectives and verbs, which have been adopted by scientists to express exact identities and procedures. They are frightening enough to the English speaking non-scientist. How much more frightening are they to the student who is a beginner in both science and English!

It has been sometimes suggested that students should be given the meanings of English stems and prefixes, which are usually based on Latin and Greek roots. This is at least a scientific approach to the problem. One linguist who advocated this method made a list of 14 English words whose roots and prefixes would provide the key to no less than 14,000 scientific words (Brown, 1964). As an example, the first word on his list was "precept" in which "pre-" means "before" and "-cept" is from the Latin verb "capere" meaning to "take" or "seize". It can be seen how knowledge of this word and other prefixes could be of help to the student in understanding such words as "intercept", "accept", "capture", etc. The same principle is applicable to many words in the secondary science textbooks. Thus the knowledge that "chlorine" is so called because it is a "green" gas can help the student to accept the more difficult word "chlorophyll" which is the "green colouring in plants.

Despite the awesome number of scientific terms which exist in English, they are usually logically derived. They are frightening, they are a burden, but ultimately and especially to the tertiary student of science, they do not present such a fundamental problem as the frame-words of discourse. The difficulty which the scientific terms pose is a difficulty in naming, whereas the connective words discussed above, which are necessary for the understanding of discourse, pose a difficulty in expressing and understanding concepts. There is a chance (and a danger) that the industrious student may memorise the nouns and verbs of science and present apparently correct factual answers to questions, while still not understanding the arguments and ideas of science. It is for this reason that mere lack of descriptive vocabulary must be considered to be less serious than poor understanding of the structure of discourse.

Only some of the problems associated with the teaching of science in English in a multilingual situation have been outlined above. There are many problems which must be faced by scientists, linguists and teachers in Singapore, as in any such

multilingual community. Rigorous thought is needed, and it is suggested that we might approach the problem with the following searching questions:

1. How can we limit and grade the vocabulary with which we communicate scientific knowledge?

2. How can we frame the precise concepts of science in terms which are at the same time true and also comprehensible?

3. How can we stimulate innovative scientific thought within the limitations imposed by the constraints of our English competence?

With the last question we return full cycle to the comments at the beginning of this article. The language which we need for the teaching and understanding of science is not merely the means

of describing, giving instructions, reporting procedures, and communicating facts. What we need is the communication of ideas. Only if we can find language which is understood by both parties to the exchange can the ideas in the mind of one scientist be communicated to another. And only by the use of this sort of communication, from mind to mind, can we hope to advance and develop in the field of science. ☞

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