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ABSTRACT

The author poses this question: When the learning of science is carried on in a foreign language, is the extent and nature of concept-formation different from that required of the student who learns science entirely in his mother tongue? Because the term "scientific concept" is ambiguous, the author suggests five distinct definitions--four groups of "generalizing concepts" and one group of "scientific concepts." While the generalizing concepts form part of the general education of most young people who reach the secondary level, the scientific concepts are specific and peculiar to various branches of science. It is important that the complexity of concepts presented at each stage not go beyond the capacity of the individual student. The same is true for language study; the problem is that many languages do not contain equivalents of the verbalizations of scientific concepts, so when scientific concepts are being learned, there could exist a certain "conceptual distance" between the two languages. The author suggests that language teaching emphasize detailed observation rather than subjective response. (FB)

THE MEDIUM OF INSTRUCTION (MOTHER-TONGUE/SECOND LANGUAGE) AND THE FORMATION OF SCIENTIFIC CONCEPTS

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THE MEDIUM OF INSTRUCTION (MOTHER-TONGUE/SECOND LANGUAGE)

AND THE FORMATION OF SCIENTIFIC CONCEPTS

This paper is about an amorphous problem: in one sense it is about certain kinds of difficulty which are encountered by students in developing states when they come to learn about science, yet have to use a foreign language to do so. In another sense it is about the organization of education in such countries, and about ways in which the drop-out may be minimised and the success rate maximised. The themes which link these two aspects of the problem are those of concept-formation and language learning. We do not know a great deal, with certainty, about either of these processes, but by analysing with some care the nature of the problem and applying to it some recent ideas a fruitful line of experiment may present itself.

Without being too precise in specifying what is meant, it is generally agreed that the education of scientists and technologists entails the understanding of a great many concepts and the ability to read, listen, talk and write about them. When the learning of science is carried on in a foreign language, is the extent and nature of concept-formation different from that required of the student who learns science entirely in his mother-tongue? The answer to this question may suggest changes in the strategies employed for learning and teaching science in the developing states.

The question hangs on the meaning of 'scientific concepts', and here we find multiple ambiguity. The term is used both loosely and with apparent precision, though the precision evaporates upon closer inspection. The various usages of the term (other than the purely conversational) relate to five distinct ideas: first, to certain linguistic skills common to all advanced academic or scholastic study; second, to certain characteristics of the habits of thought of the individual scientist; third, to a number of concepts prerequisite to science but not unique to it; fourth, to one special prerequisite, that of practical numeracy; and fifth, to those concepts which are unique and proper to science, or which if they are not unique to it are at least inseparable from it. We shall look in turn at each of these uses of the term 'scientific concepts'.

English, French and all the languages commonly used for advanced scientific study possess a group of words and expressions which I shall call the grammatico-logical operators. Presumably all languages possess some roughly equivalent list of items. They are essential for expressing any kind of complex, abstract, and especially recursively-abstract ideas, whether scientific or not. In English the set of grammatico-logical operators includes at least the following:-

although	once (something has occurred)
as a result of	only (e.g. only if...)
as if	suppose.....then.....
as long as	since (something has occurred)
because	therefore
for the purpose of	unless
if, if.....then....	until
in order to	whenever

etc. etc.

These items are vital not only to an understanding of science but equally to complex logical thought and verbalisation in any field of discourse. Mastery of these items is normally confined to those whose education reaches the higher secondary level, and it may be determined by intelligence.

A second set of ideas which are frequently spoken of as 'scientific concepts' comprises a certain objectivity of outlook on the universe, on the part of the individual, together with an ability to generalise from observation and to perceive and describe relationships and influences. It is customary to regard a preference for an objective, descriptive, rational outlook, or alternatively for a subjective, impressionistic, non-rational outlook, as if these attitudes were inherent to the individual personality. I find this difficult to believe. Knowing of no evidence to the contrary my intuition suggests that such preferences are learned behaviour. If that is so, these attitudes may not be determined by intelligence and may be open to acquisition by all individuals, although it may well be that there is a developmental age at which they are more easily learned than at any subsequent time.

The third group of notions for which the label 'scientific concepts' is sometimes used includes being able to deliberately generalise from observations, to talk abstractly about the generalisations, and to discern and describe relationships, influences and patterns. These abilities seem to relate to aspects of intelligence in the individual, as well as to a fairly late stage of mental development.

The fourth type of idea of 'scientific concepts' is practical numeracy: the ability to carry out a certain amount of mental arithmetic, to visualise in graphs and diagrams, to take for granted the use of statistical statements -- above all a willingness to describe by quantifying. These abilities, like all the preceding ones, are essential for learning science. But they also form part of the general education of most young people whose education reaches the upper secondary level, whether or not they later specialise in science.

All four of these sets of ideas are necessary for the learner of science if he is to progress very far; they also form part of the education of specialists in other branches of learning. I shall refer to the four preceding sets of ideas as the 'generalising concepts', in contrast to those unique or essential to science, which I shall refer to as the 'scientific concepts'. Because they are prerequisites for the education of the scientist, the generalising concepts cannot be ignored. They must be seen to constitute a learning problem of a conceptualising kind for <u>all</u> advanced learners. When the learning is in a foreign language the same question arises as for science: is the task of concept-formation different, compared with learning in the mother-tongue?

Within the concepts unique and proper to science it is possible to recognise large numbers of sets of concepts corresponding to different branches of science, different stages of general scientific discourse, different specialisations. A number of examples of sets of generalisations and concepts are given in the Appendix to illustrate this point.

Every human being learns to form a great many concepts, and to verbalise some of them. Every language expresses the concepts habitually used in the society it belongs to. In each case there is a wide range of variation. Taking the individual first, there is a great deal of variation between the degrees of recursive abstraction which can be effectively handled, whether receptively or productively, by different individuals. (We are considering here not just the sub-set of concepts embodied in and manipulated by such operators as unless, although, whenever, etc. but concepts in general, very many of which are not verbalised.) One of the functions of education is (or ought to be) to steer each individual to the limits of his capacity in developing concepts; one of the tasks within science education is to ensure that the complexity of the concepts being presented at each stage is not beyond the capacity of the individuals concerned.

As far as languages are concerned, it is necessary to distinguish what is from what could be. Very many languages do not at the present time incorporate equivalents of the verbalisations of scientific concepts which exist in English, French, Russian and the other languages in which scientific study is customarily pursued. But we should avoid falling into the error of arrogance and feeling that these languages are therefore in some sense defective, inferior or primitive. A language reflects the culture of a particular society. If that society includes science within its culture, the language will contain all the necessary concepts and devices for talking and writing about science. If a society with no previous history of scientific interest begins to acquire such in interest, its language -- any language -- can and will develop internal grammatical and semantic rules for doing so. (Hebrew is an example of a language in which this process has taken place in modern times.) Unfortunately the task of developing scientific concepts ab initio in a language takes a good many years and can only rarely be engineered as a deliberate policy. Such development does not constitute a practical solution to the shorter-term problems of science education.

Languages vary, then, in the extent to which they give expression to both generalising and scientific concepts. In saying this we are categorising the mother tongues of potential scientists, who may thus have been brought up speaking a language which carries either all, or many, or few of the total range of concepts relevant to education in science. What difference does this make to the education of the individual? The answer depends not only on the extent to which generalising and scientific concepts are present in his mother-tongue, but perhaps even more upon his age and the extent of his education in his mother-tongue before beginning to learn science.

The young child who begins to learn science in an educational system where English or French (for example) is the medium of instruction from the beginning of schooling will be relatively little affected, compared with the adult, already literate in his mother tongue and thoroughly imbued with the culture of his own society, whose encounter with science comes after the completion of adolescence. In the case of the young child, his learning of concepts and his grasp of the more complex devices of his languages are still largely before him. The fact that they may include generalising and scientific concepts which otherwise he might not have met at all, and even the fact that he may face a language-learning task that he might not otherwise have had to surmount -- these considerations are counterbalanced by two others: first, that his learning load is not X followed by Y, as in the case of the adult, but rather an amalgam of X and Y; and second, that the learning comes at an earlier period in his personal development, when concept-formation seems to be at its most plastic and insouciant. The adult, on the other hand, faces a learning load which is truly an addition, and he does so at a different and perhaps less favourable stage of personal development.

In the past two or three years, a group of specialists working in the area where the disciplines of psychology and linguistics overlap have proposed ideas concerning the acquisition by the child of his mother-tongue. Some of the ideas are of interest in the context of this present discussion. Broadly, it is held that the normal child passes through a series of phases of brain development; these in turn produce states of readiness for different kinds of mental organisations of the stimuli preceived from the child's surroundings. The wellknown successive stages of undifferentiated cries, babbling, word-and sentence-formation, etc. are thus seen as occurring similarly in _all_ children and as being the result of physiological and organisational changes in the brain.

The stages of the process, during which the child begins to understand language and to produce acceptable utterances, are described in terms of a growing _competence_ to produce language rather than in terms of the child's actual _performance_ at a given moment. The child is seen to observe, remember and recall utterances, but he is not limited in what he can understand and say by the precise utterances he has already encountered: he understands unfamiliar utterances by their adherence to _rules_ for generating sentences, rules which he is gradually working out and operating for himself; and he speaks sentences which in many cases he has never heard before by applying the rules which he has so far mastered. The mastery of the rules, it seems, also proceeds through a series of stages common to all children, with the result that what are usually called "childish errors" may be better described as the products of the normal sequence of rule-acquisition. By the age of 4 or 5 years, it is held, the child has largely mastered the basic sentence-construction rules of his mother-tongue.

This model of language-acquisition (which is associated with the names of Chomsky, Miller and others) has two main points of interest for our argument. First, the acquisition of language entails the acquisition of a very large number of concepts: number, singularity, duality, gender, animateness, tense, pre-suppositions of various kinds, even causality and subordination, and great many more. The set of inherent concepts within language we will label the "language-borne concepts". If the Chomsky model adequately represents what happens in acquiring the mother tongue, it also represents (though in a manner not clearly defined) the acquisition of some concepts, notably the language-borne ones. They, too, may be built up into a framework of mental _competence_, in the sense of potentiality for exploitation, in which the limiting parameters are the stages of brain development on the one hand and the child's particular, personal experience of the universe on the other. Secondly, it is conceivable that normal development permits the growth of certain basic stock of concepts and of conceptualising competence common to all normal children regardless of individual differences of intelligence.

However, illuminating as this model of language acquisition may be, there is no doubt that normal children do develop further in language achievement and ability after the age of 4 or 5, and that individual differences are clearly visible in the extent and nature of their subsequent development. We usually refer to this in terms of "creative ability" or of "stylistic awareness", criteria which are based on the literary norms of our society. But there exists also a second and non-literary type of linguistic achievement which I believe can be expressed as the ability to handle with accuracy and precision the grammatico-logical operators of the language. Not all children manage this. Those who fall short also under-achieve in relation to the complexity of many of the other generalising concepts; achievement in this domain seems to correlate with intelligence above the normal.

We need to remember that the notions of a model of language acquisition have been developed in relation to the mother-tongue. Much less attention has been given to the mental processes of acquiring a subsequent language. Some of the concepts embodied within language (for example those which underlie language universals) will be common to mother-tongue and foreign language alike; others in the foreign language will be unfamiliar. A "conceptual distance" between the two languages could be expressed in relation to three factors: degrees of linguistic cognate-ness; degrees of equivalence and similarity of writing system (whether they both run from left to right, horizontal or vertical, Roman, Cyrillic, etc.): and degrees of semantic and cultural similarity. The smaller the conceptual distance, presumably the smaller the learning task, other things being equal.

What is clear, from generations of experience, is that concepts <u>can</u> be learned in a foreign language. As the foreign language is learned, the language-borne concepts are themselves learned; as competence in the foreign language advances, if the opportunity presents itself and if the individual has the ability, the generalising concepts may also be learned; similarly, under appropriate conditions the concepts of science may be learned, as well.

If one looks at the fairly rare but not unknown case (until now perhaps the "target" case) of a learner successfully learning advanced science in and through a foreign language, at least the following over-lapping stages can be distinguished: first, the acquisition of a minimum basic competence in the foreign language (to roughly that point well-known to teachers but difficult to specify where a learner ceases to be a "beginner" and starts to become "advanced"); second, the acquisition of control in the foreign language of the generalising concepts and particularly of the grammatico-logical operators; third, assimilation of the concepts of science; and fourth, simultaneously with all the other three stages, the learning of scientific vocabulary. (The learning of science in a foreign language is emphatically not a matter of vocabulary. If the events of the science syllabus are understood, and if the concepts embodied in them are grasped, the vocabulary items become no burden either for learner or teacher.)

It is not at all certain how far the <u>learning</u> of science and its concepts in a foreign language is made more effective by the manner of its <u>teaching</u>. What is almost universally the case is that foreign languages are taught with aims unrelated to science, and even where the foreign language is used in the teaching of science this is done with little professional acknowledgment of the special conceptual tasks facing the foreign learner. "First he learns English (or French, etc.); then he is taught science as an English learner is taught."

The underlying educational policy is to teach the foreign language to all the members of a certain tranche of the population, and to select from among them, after they have been learning English for a given period of years, a further sub-set who will then be taught science. But the aims of teaching English to a major group of learners have almost always been defined in terms of general culture: these terms are in practice largely literary. Even where lip-service is paid to the need for a foreign language as a tool, as a means of communication, or as a force of cohesion, analysis of the English syllabus nearly always reveals that it is leading up to the study of Shakespeare, Wordsworth or Dickens, and that its concepts are the subjective, aesthetic ones of literary studies. In many cases, too, the bias of the syllabus and teacher alike is openly <u>anti</u>-scientific, rejecting detailed observation in favour of the subjective response.

It is not my purpose to criticise these attitudes for their own sake. But if we look at the education of scientists we discover that <u>before</u> they start to learn science a great number of overseas learners are first taught a foreign language according to syllabuses that are in some sense opposed to the attitudes of science. What is worse, in most countries the general effectiveness of the teaching of a foreign language, although it may be better than it was fifty years ago, is by no means high or even encouraging. The results of this are reflected at least partly in the short-fall in the education of scientists, engineers, technologists and fitters.

It can be argued that a high proportion of the teaching and learning effort in the foreign language which students of science undergo <u>before</u> they embark on science is wasted. Much of it is wasted because it is irrelevant to the needs of the scientist; some is wasted because it is ineffectively learned and taught.

Bringing together the various considerations raised in this paper so far, it is possible to suggest that a measurable and possibly a major increase in the effectiveness of science education might be achieved if the priorities were reversed, so that the foreign language was taught for science and through science in the first instance, with special attention paid to the deliberate inclusion of the generalising concepts in the language course, as well as the special concepts of science. Not all pupils would show the ability or the preference to follow advanced courses in science. Those who fell by the wayside would be selected for the continuation along general cultural and literary lines. Under this strategy <u>all</u> learners would have the oportunity to achieve their potential in science, and only a minority would study literature, instead of the other way round. This seems to me to make much better sense in the condition of most developing states.

A science-oriented language syllabus is entirely feasible. All the basic teaching of a foreign language can just as easily be placed in the framework of learning science as in a framework of everyday discourse (which is in fact what the present syllabuses teach in the early stages). Of course the syllabus must take account of the age and interests of the learner, but there are few existing English or French courses that would not be improved and rendered vastly more interesting to the learners by (for example) replacing stories of King Arthur and the Round Table by extracts from current science fiction, or replacing scenes from the French Revolution by texts about supersonic flight or the potentialities of computers. Much of the effort currently expended in teaching potential engineers in tropical Africa about daffodils or about manners in nineteenth century England could with profit be re-channelled through syllabuses whose ultimate aims include the preparation of citizens with adequate scientific and technical understanding.

Let me be clear: I envisage the creation of a syllabus and of a full range of teaching materials for particular levels and age-groups, in which English (or French) would be taught from the beginning in the framework of a science course, and science would be taught in English. In such a syllabus the choice of linguistic content would be determined in the first instance by the requirements of the science syllabus; the various categories of concept-formation discussed in this paper would receive deliberate treatment; accompanying materials would all be geared to the aim of exploiting to the maximum the science potential of each learner.

Such a course of action would face considerable difficulties, not only in its preparation but also in the re-training of teachers. Many teachers would find it difficult to adjust their outlook from the artistic imprecision of a "general-cultural" base. The administrative problems would also be great. Nevertheless in the present state of affairs only some such drastic remedy seems likely to provide a massive improvement in the effectiveness of science education in the developing countries.

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June 1969

APPENDIX:

Some non-comprehensive examples of types of scientific concept and linguistic-conceptual device

1. Linguistic additives

a)

a-
anti-
ante-
co-
contra-
extra-
non-
pre-
post-
re-
sub- etc.

b)

-ate
-ation
-ator
-able, -ible
-al
-ic, -ical
-ise
-isation etc.

2. Some conceptual processes involved in learning science

classifying
measuring
space-time relations
communicating
inferring
observing
quantifying
abstraction-making
generalising
model-making
hypothesis-making
testing
theorising
predicing
replicating
extrapolating etc.

3. Some basic scientific concepts

observation
identification
differentation
classification
experiment
description etc.

4. Examples of some "experimental" notions

crystallise
evaporate
volume
pressure
flow
vacuum
electrode
hydrolysis
distillate
residue

etc. etc.

5. Another group of terms: how should they be labelled?

force
field
flux
influence
attraction
repulsion
rotation
spin
precession

etc. etc.

6. Some "theoretical" concepts

evidence	axiom
support	law
confirm	principle
model	corollary
stand/fall	hypothesis
interesting	validate, valid, invalid
trivial	tenable, untenable
irrelevant	infer
important	suppose
postulate	assume
prefer	pre-supposition
reject	

etc. etc.

7. Some "mathematical" concepts

alike
different
greater
less
include
exclude
increase
decrease
reduce
member
class
unit
set
add
subtract, take away
combine
separate
order
sequence, sequential
simultaneous
precede
follow
subsequent
zero
infinite
indefinite
random

etc. etc.

NOTE: The object of the examples in this Appendix is to remind the reader of a few of the very large number of concepts that need to be learned, and of the way they contain both isolated items and items that can be grouped in a more or less helpful way with other items.