SECTION TWO

English for Science and Technology

These three papers are concerned with how one might characterize and teach the English used in science and technology, particularly as realized in written communication. They focus on different aspects of the question and so can be located at different points on the applied linguistic spectrum. The first is directed towards the design of classroom exercises, the second discusses the relationship between such pedagogic practice and description based on theory, and the third attempts to clarify and illustrate theoretical distinctions assumed in the preceding papers.

Much of the discussion centres on two major and interrelated themes. The first of these has to do with the characterization of scientific and technical English. The argument here is that the formal linguistic characteristics of these varieties or 'registers' of English are only of interest as realizations of underlying concepts and communicative operations associated with particular areas of inquiry which go under the general name of science and technology. Scientific and technical English is thus represented not as a variety of English text but as a textualization of a variety of discourse which is itself independent of any particular language and expressive of a secondary and universal culture which scientists and technologists acquire through education.

The second theme draws out the pedagogic implications of the first. If one conceives of EST as varieties of English text, in contrast, let us say, to other varieties of text like sermons, cooking recipes, sports reports, and what have you, then there is clearly little scope for learner participation when it comes to teaching it. We are pushed towards a unilateral pedagogy in which the direction is from the teacher to the learner since the former knows the English textual forms and the latter does not. If, on the other hand, one conceives of EST as varieties of discourse textualized in English, in contrast, let us say, to other textualizations in German, French, Russian, and so on, then, of course, the case is very different. Here the learner has a knowledge of the discourse which corresponds to his stage of learning in the area of science and technology concerned; and he can use that knowledge as a base for learning the particular textualization of this discourse in English. This way of conceiving of EST, therefore, would seem to lead naturally to a bilateral approach to pedagogy which

can engage the participation of the learner by making open appeal to what he already knows.

A development of this second theme takes us on to the drafting of exercise types which might ensure learner engagement. This development is demonstrated in Paper 4 in this section and the papers in the section which follows illustrate further exploration along these lines. The first theme, that which has to do with the nature of discourse, is then taken up again in Section Four.

2 An approach to the teaching of scientific English discourse

Introduction

This paper has two complementary aims. The first relates to language teaching methodology: I want to make a number of practical suggestions as to how to approach the teaching of English to students who need to know the language in order to pursue their studies of science and technology in higher education. The second aim relates to applied linguistics: I want to make explicit the process whereby I arrived at these suggestions. All proposals about how language should be or might be taught derive from notions about the nature of language and language learning. Where these notions are not made explicit, however, it is difficult to assess the potential value of the proposals (their *actual* value can only emerge through trying them out in the classroom) or to identify which aspects are unsatisfactory. The teacher accepts or rejects them but he has no clear indication as to how they might be modified to suit his particular circumstances. He may adopt, but he may not be able to adapt.

In the first part of the paper, therefore, I shall be concerned with establishing a certain theoretical orientation to language study which I believe to be of particular relevance to the specialist English teaching purposes that have been mentioned. In the second part I shall try to show how certain principles of approach to language teaching seem to derive naturally from this orientation and how exercises based on these principles might be devised. I shall proceed, then, from theoretical considerations concerning the nature of language through certain principles of language teaching methodology to a set of practical proposals for the teaching of English to students who need the language to service their specialist studies.

I

The special English requirements of students following higher education courses in science and technology have been recognized for some time and a good deal of material has been produced to meet these requirements. It is important to notice, to begin with, that the underlying the-

oretical basis of most of it (though this is not always made explicit) is traceable to the concept of register. This being so, it would seem to be an appropriate point of departure for the theoretical part of my paper to consider the validity of this concept.

We may begin by examining how the notion is introduced in Halliday, McIntosh, and Strevens:

> Language varies as its function varies: it differs in different situations. The name given to a variety of a language distinguished according to use is 'register'.
> *Halliday et al 1964: 87.*

There is an underlying assumption here which I think is questionable. It is as follows: since language in general varies in accordance with the functions it is required to fulfil, then it follows that *a* language in particular must consist of different and distinct varieties. Furthermore, these varieties are defined in terms of their linguistic characteristics as subcodes of a particular language. As Halliday, McIntosh, and Strevens put it:

> It is by their formal properties that registers are defined.

I want to suggest that the argument upon which the notion of register is based rests on a double fallacy. On the one hand the fact of language variation is thought to entail the existence of separate language varieties within a language and on the other hand functional variation is thought to entail the existence of these varieties as formally distinct subcodes. It seems to me that there is a confusion here between *language* and *a language* and between *form* and *function*. In fact, variation in language (in general) need not involve the existence of varieties in any particular language and different functions need not be matched by a difference of linguistic forms.

Registers, then, are represented as formally differentiated varieties of a particular language. Thus we hear of a 'type of English' which is used for church services, or engineering textbooks, or cooking recipes. We are told that there is 'an English' of commercial correspondence or agriculture which can be described in terms of its lexical and syntactic properties. In accordance with this view of functional variation, language teachers engaged in preparing English materials for students of science and technology and other specialist areas of use have supposed that their task involves simply the selection and presentation of those lexical and syntactic features which occur most commonly in passages of English dealing with the specialist topics their students are concerned with. My view is that although such materials can serve some of the language needs for

which they are intended, those, in fact, which have to do with a knowledge of the language system, they do not provide, except incidentally, for other needs, which have to do with a knowledge of the communicative functioning of the language. To meet needs of this kind I believe that we need to base teaching materials on a different theoretical approach to language variation.

What I want to suggest is that specialist uses of language, such as we find in scientific papers, technical reports, textbooks of different technologies, and so forth, are not to be associated with formally different varieties in a particular language but with certain universal modes of communication which cut across individual languages. That is to say I want to shift the theoretical orientation from particular languages to language in general and from linguistic forms to communicative functions. As a first step towards establishing this orientation let me make a distinction between *text* and *discourse*.

When confronted with a sample of language, a chapter in a chemistry textbook, for example, there are two ways in which we might describe it. We may treat it as an exemplification of the language system and point out the incidence of certain linguistic structures and items of vocabulary: in other words, we can describe its formal properties as an instance of linguistic usage. To do this is to conduct a register analysis and to characterize the sample as *text*. If we treat the sample in this way, however, there are a number of things about it that we fail to account for. In the first place it clearly does not just exist as usage, as an exemplification of the language system: it is also an instance of use; it communicates something and does so in a certain manner. If we were to ask the author or the reader to describe the sample, the likelihood is that he would characterize it as a *description* or a *report* or a set of *instructions*, or an *account* of an experiment. These terms do not refer to the linguistic properties of the sample as text, but to the communicative function of the sample as *discourse*. A register analysis of the sample as text will tell us nothing about these communicative functions of language use.

Furthermore, it will not account for another aspect of the sample. Much of the communication in a chemistry textbook is effected by other than verbal means. Apart from the purely verbal parts of the sample there will be formulae, symbols, line drawings, and tables which are an essential and intrinsic part of the communication as a whole. Since they do not exemplify the language system an analysis of the sample as text will, of course, make no reference to these communicative elements at all. An analysis of the sample as discourse, the purpose of which is precisely to characterize the communication as a whole, must take into account both verbal and non-verbal features and the manner in which they are related.

Once we shift the centre of attention from the linguistic properties of a piece of language as text to its communicative functioning (comprising both verbal and non-verbal modes) as discourse, it becomes plain that we are no longer dealing with the features of a particular language. Whether one is using English or French, Indonesian or Chinese, one is obliged, as a scientist, to perform acts, like descriptions, reports, instructions, accounts, deductions, the making of hypotheses, and the calculating of results. These are some of the basic cognitive and methodological processes of scientific inquiry and if one does not follow them, one presumably ceases to be scientific. What I am suggesting, then, is that the way English is used in science and in other specialist subjects of higher education may be more satisfactorily described not as formally defined varieties of English, but as realizations of universal sets of concepts and methods or procedures which define disciplines or areas of inquiry independently of any particular language. In other words, the 'special uses' we have been referring to are the communicative functions of language in a general sense and constitute universes of discourse which underlie the different textual features which realize them in different languages.

It is possible to reformulate the points that have been made in the previous paragraph by reference to the familiar distinction between deep and surface structure. We might say that the deep structure of, say, communication in chemistry, is the universe of discourse which consists of the concepts and procedures of this discipline, and the incidence of particular linguistic features in English chemical texts is simply the surface structure manifestation of these deep structure elements. How can this deep structure be represented? It seems reasonable to suppose that at least a part of its representation is to be found in those universal features which appear overtly as intrinsic elements in the discourse itself: that is to say, the non-verbal modes of communication like formulae, tables, diagrams, and so on. In chemical discourse, for example, whether the purely verbal part is expressed in English, Thai, or any other language, we will find devices like symbols and equations, diagrams of processes, and models of chemical compounds. Since these are drawn from a universally accepted set of conventions for representing specific concepts and procedures in chemistry they can be said to constitute part of the deep structure of chemical discourse. This deep structure, then, appears as it were, on the surface. But it can also be given a range of surface forms as it is verbalized in different languages.

Let us consider an example. The following is part of the discourse of an elementary textbook on chemistry:

$$H_2O + CO_2 \rightarrow H_2 CO_3$$

These symbols and their combination to form this equation are likely to occur in any elementary chemistry textbook in any language. They are elements of a universal symbolic system. Thus, individual symbols like H, O, C, which represent chemical elements, can be regarded as the morphemes of this system, and the combination of symbols like H_2O, CO_2, which represent chemical compounds, can be regarded as the words. All of these 'words' are nominals since verbals are represented by the constants + and →. The whole formula constitutes a 'sentence' of this symbolic system, and the rules generate 'sentences' of this kind which are in essence the laws of chemical processes. Now this deep structure formula can be verbalized in terms of the linguistic system of a particular language. A surface form expression of it in English might be the following:

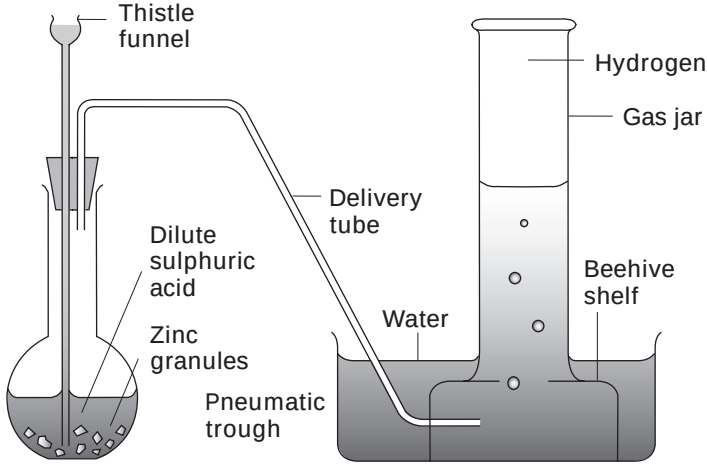
$$H_2 \quad O \quad + \quad C \quad O_2 \quad \rightarrow \quad H_2 \quad CO_3$$

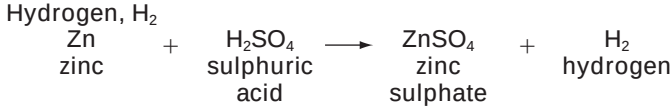
hydrogen oxide carbon dioxide hydrogen carbonate
water combines with carbon dioxide to form carbonic acid

In terms of linguistic usage this is an English sentence, but in terms of communicative use it is a general statement expressing a chemical fact. The same formula can be said to underlie a different kind of communicative act such as a definition:

Carbonic acid is a compound which consists of water and carbon dioxide.

Both general statements and definitions are facts which have to do with the abstract conceptual content of a discipline, and we may say that the chemical formula we have been considering is an expression of content of this sort from which such acts can be derived. What the formula does not do is to tell us how the process takes place: it cannot, in other words, provide the underlying basis for a description of the process whereby carbonic acid is produced. This is a procedural matter. But just as we have formulae which express the *conceptual* aspects of the deep structure of chemical discourse, so we have other universally accepted non-verbal representations of the *procedural* aspects. Consider, for example, the following:





Here we have a formulaic representation of a process as an abstraction from which can be derived general statements and definitions together with a conventional diagram illustrating the process as a concrete event from which can be derived such acts as instructions, descriptions, and reports. For example:

Instructions
Place zinc granules in a flask fitted with a thistle funnel and a delivery tube. Place the other end of the delivery tube in a pneumatic trough. Fill the trough with water . . . etc.

Description
Dilute sulphuric acid is added to zinc granules in a flask fitted with a thistle funnel and delivery tube. A chemical reaction takes place and hydrogen is given off . . . etc.

Report
Dilute sulphuric acid was added to zinc granules in a flask which had been fitted with a thistle funnel and a delivery tube . . . etc.

Let me now summarize the main points that have been made. The proposal is that we should think of 'scientific English' not as a kind of

text, that is to say as a variety of English defined in terms of its formal properties, but as a kind of discourse, that is to say a way of using English to realize universal notions associated with scientific inquiry. These notions have to do with the concepts and procedures of particular branches of science which serve to define these branches as disciplines and which are expressed non-verbally in the same way, whichever language is used in the verbal parts of the discourse. In the area of science that I have chosen to illustrate this, the concepts seem to be expressed through formulae which represent the basis for such communicative acts as definitions and general statements, and the methods or procedures seem to be expressed through conventionalized diagrams which represent the basis for such acts as instructions or directions, descriptions, and reports. This may turn out, after further investigation, to be too neat a division for chemical discourse, and of course a different set of divisions may be necessary for other areas of science. But the main point is that there seems to be a universal underlying structure to different areas of scientific discourse which is neutral in respect of the different languages which are used to realize it, and that this underlying structure seems to be made overt through non-verbal modes of communicating. From this point of view, 'scientific' English relating to a particular discipline is not described formally as a type of text distinguishable from other 'registers' or 'varieties' in terms of its linguistic properties, but as the realization of a type of discourse which is defined in functional terms and distinguishable from other uses of language in general in terms of what concepts and procedures are communicated.

Let us now consider what pedagogic implications arise from this theoretical orientation to the study of language use.

II

I have argued that the English of different areas of science and technology (and probably other disciplines as well) can be regarded as particular linguistic realizations of uses of language in a general sense to express the concepts and procedures which define these areas of inquiry as disciplines. These universal defining features find a partial realization in non-verbal modes of communicating which constitute a universal set of symbolic devices for conveying the concepts and procedures of particular disciplines. Now the student entering higher education will have already been initiated into these concepts and procedures as they are realized both through his own language and through non-verbal symbolization. Thus, he already knows a good deal of how scientific communication is carried out. What he does not know is how it is carried out through the use of the particular linguistic

system of English. The task of the English teacher at this point, therefore, is to extend the range of the student's communicative ability by making him aware of an alternative way of expressing the knowledge of science he already has.

One pedagogic principle that would seem to emerge from the orientation to language study that has been outlined in this paper, then, is that a course which prepares students for dealing with English use in scientific communication should present the language not as something in isolation from what the students already know but as an aspect of something with which they are already familiar. Let us now consider how we might put this principle into practice. We will assume that we wish to use chemistry as the area of science with which to associate the use of English. This does not preclude the possibility of associating English with other areas at a later stage; nor does it mean that the English which is learnt will only be relevant to students specializing in chemistry. I will return to this latter point later on. For the moment, let us suppose that we are concerned with the preparation of an English course for science students at the late secondary or early tertiary stage, that these students have had some basic grounding in science (including chemistry) and in English, and that our aim is to prepare them for their encounter with scientific communication in English such as they will find in their textbooks.

As an early, limbering-up, exercise we might require the students to make reference to, and relate, a knowledge of scientific symbols, their own language and English in the completion of a table. To complete the table they might well need to refer both to a dictionary of English and to a textbook on chemistry, and this is all to the good because such activities will help to impress upon the student right from the start that the English he is learning has an immediate bearing on the solving of a scientific task. The following is an example of the kind of task I have in mind:

Complete the following table. Refer to an English dictionary and to a chemistry textbook if necessary.

1	2		3	4
symbol	name		atomic number	atomic weight
	L1	English		
S				
Ca				
Cl				
H				
O				
Pb				
Fe				
Cu				
Zn				
Na				

We might next present a second table representing atoms and molecules and ask the student to make simple statements in his own language based on the table and to recognize and later to reproduce comparable statements in English.

For example:

atoms	molecules
Cl	Cl_2
H	H
O	O_2
S	S_8
Fe	Fe
Pb	Pb
Cu	Cu_2

Statements in L1	*Statements in English*
.....	A chlorine molecule consists of two chlorine atoms.
.....	A molecule of chlorine consists of two atoms of chlorine.
.....	Chlorine molecules consist of two chlorine atoms.
.....	Molecules of chlorine consist of two atoms of chlorine.
.....	A sulphur molecule consists of .....
.....	A ..... consists of eight atoms of sulphur.
.....	Sulphur molecules ..... eight sulphur atoms.
.....	Molecules of sulphur .....

Other exercises of a similar kind might be introduced which gradually involve more productive participation on the part of the student, each one requiring him to realize the relationship between a symbolic representation, an expression in his own language, and an expression in English. We might, for example, go on to present a table of elements and compounds and get the student to provide names in his own language and to make appropriate statements.

Elements	Compounds	Name in L1	Name in English
Cu	CuO		
Cl	$CuCl_2$		
Fe	Fe_2O_3		
Pb	PbO		
S	CuS		

Statements in L1		*Statements in English*
.....	Cu	Copper is an element.
.....	Cu, Cl	Copper and chlorine are elements.
.....	Fe	Iron .....
.....	Fe, Pb	..... are .....
.....	CuO	Copper oxide is a compound.
.....	PbO	Lead oxide is a compound.
.....	CuO,pbO	Copper oxide and lead oxide are compounds.
.....	Fe_2O_3	Iron oxide .....
.....	CuS	..... sulphide ..... a.....
.....	CuS, $CuCl_2$	..... and copper chloride ..... compounds.

Consider the next exercise.

Statements in L1		*Statements in English*
.....	$CuCl_2$	Copper chloride is a compound.
.....		It consists of one atom of copper and two atoms of chlorine.
.....		Copper chloride is a compound which consists of one atom of copper and two atoms of chlorine.
.....		Copper chloride is a compound consisting of one atom of copper and two atoms of chlorine.
.....	Fe_2O_2	..... is a compound.
.....		..... consists of ..... and three .....
.....		..... oxide is a compound which consists of ..... of iron and ..... of .....
		..... a compound ..... two atoms of iron and .....

As a development of the last two exercises, we might now ask the students to understand first and then write out two statements followed by a single statement which combines the two.

So far the communicative acts which we have required the student to understand and perform might be characterized as simple classifying statements like *copper is an element*, *copper oxide is a compound*, general statements or generalizations concerning composition like a *chlorine molecule consists of two chlorine atoms* and combinations of these two acts which yield defining statements, or definitions, like *copper chlorine is a compound which consists of one atom of copper and two atoms of chlorine*. We may now proceed to other uses of English: to simple statements about processes, for example. To do this we might present a set of equations such as were referred to in part I of this paper and derive appropriate statements from them in the following manner:

Statements in L1	*Statements in English*
..... $Fe + S \rightarrow FeS$	Iron combines with sulphur to form ferrous sulphide.
..... $2Mg + O_2 \rightarrow 2MgO$	Magnesium combines with oxygen to form magnesium oxide.
⋮	⋮
..... $2NA + Cl_2 \rightarrow 2NaCl$	Sodium ..... chlorine .... sodium chloride.

It should be noted that the focus of attention in all of the exercises that have been suggested is on the way English functions in the performance of certain acts of communication which are central to scientific inquiry in general, although exemplified in this particular instance by chemistry. But although the focus is on use, the students are, of course, being given practice in usage at the same time: that is to say they are exercising their ability to compose correct sentences in the process of performing appropriate acts of communication. What this approach enables us to do is to bring together sentence patterns which have been learnt in separation in different parts of a school course and to show how they can be associated as realizing the same communicative function. In this way we draw on the student's previous knowledge and give it a new significance so that its relevance to scientific study becomes apparent.

The kind of communicative acts we have dealt with so far are those which are expressive of some of the concepts of chemistry and these acts

(classification, generalization, definition) are of course expressive of concepts in other scientific disciplines as well and can be regarded as features of the basic rhetoric of science. Thus what the student is learning is not simply how the concepts of chemistry are expressed but a set of communicative acts which have a much wider range of employment. We might, at this stage, wish to bring this home to the students by illustrating the use of these acts in the expression of the conceptual content of other scientific areas.

From communicative acts based on formulae and equations relating to concepts we might next proceed to communicative acts based on diagrams relating to procedures. For example, an equation like the following:

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

provides a basis for general statements of fact like:

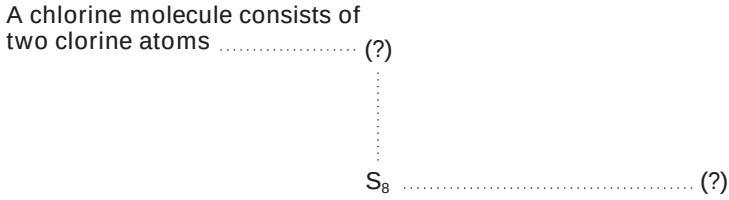
> Zinc combines with sulphuric acid to form zinc sulphate and hydrogen is given off.
> When zinc combines with sulphuric acid, zinc sulphate is formed and hydrogen is given off.

and so on. The equation provides a basis for making factual statements to the effect that a certain reaction takes place: it does not provide a basis for the description of how we must proceed to bring about such a reaction. The kind of non-verbal device which does provide such a basis is a diagram of the kind which was illustrated in the first part of this paper. As was pointed out there, from such a diagram can be derived acts like instructions, descriptions, and reports and these acts can be realized as before, both in the student's own language and in English. Again, it should be noted that these acts can relate to a much wider range of procedures than those specifically associated with chemistry and exercises drawing on other scientific areas may be devised accordingly.

The shift of attention from acts relating to concepts to acts relating to procedures also tends to involve a transition from structurally simple acts consisting mainly of one utterance to more complex ones consisting of a combination of utterances. We now begin to approach the kind of discourse which the students will encounter in their textbooks. At the same time, we might wish to withdraw the help given by the use of the L1 and place an increased emphasis on the use of English. We still maintain the principle that what is to be learnt should be related to what is already known, but what is already known is now the knowledge of English and its operation that the course itself has developed. With the removal of the L1-English link, more reliance will have to be

placed on the relationship between English and non-verbal representations and these can be exploited more fully to give meaning and point to the language being learnt. Let us now consider how this might be done.

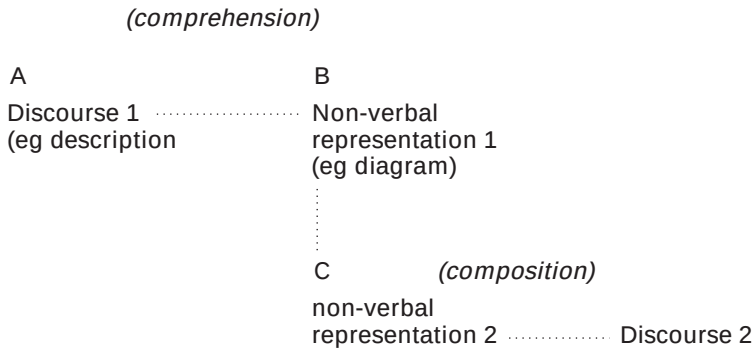
In the exercises that have been suggested so far, statements in English have been associated with statements in the L1 and with non-verbal representations of one kind or another. The student's task has been initially to recognize the value of the statements and subsequently to participate in making statements of a similar kind. Another way of exploiting these representations which could follow on from this would be to have students derive an appropriate representation from a statement or a set of statements and the reverse. For example:



Here, the student is required to provide the formula Cl_2 to correspond with the first statement and the statement *A sulphur molecule consists of eight sulphur atoms* to correspond with the formula which is given. The degree of similarity of the two formulae controls the extent to which the first statement (the one which is given) serves as a model for the statement which the student has to provide for himself. This simple scheme allows for reception and production (comprehension and composition) to be related in a controlled way as aspects of the same language learning process.

Now when we come to the teaching of acts relating to procedures like descriptions, reports, and instructions without recourse to an overt relationship with the way these acts are realized in the L1, we can exploit this scheme more fully. For example, a description of an experiment might be given and the student required to label or complete a diagram, or draw one, which illustrates what is described. This is a comprehension task. Next, the student is given a diagram comparable to the one he has completed or drawn and is required to derive a description from it which will be correspondingly similar to the original description, which

serves therefore as a model. Deriving a description from a diagram is, of course, a composition task. We can represent these proposals more generally as follows:



In this diagram (and in the previous one), the dotted lines (both vertical and horizontal) represent where control can be exerted. It can be exerted between A and B by varying the degree of difficulty of the task given to the student. He may be presented with a partially labelled diagram, for example, or a diagram with no labels, or an incompletely drawn diagram, or no diagram at all. Similarly, the task of moving from C to D can be made more or less difficult: the student can be provided with certain key words or phrases, or be asked to complete a discourse by filling spaces, or be asked to compose the discourse without any clues at all. The control between B and C has to do with the degree of similarity of the non-verbal representations: and this will determine, of course, the extent to which Discourse 1 can serve as a model for Discourse 2.

Conclusion

In this paper I have tried to show how the adoption of a certain view of the nature of language and how it is learnt can lead to proposals for language learning exercises. I have suggested that if one considers the way English is used in science as the realization of universal modes of thought and practice and not as a formally defined 'register' of English then it follows that it should be presented in association with corresponding uses of the first language and with those non-verbal means of expression which realize the concepts and procedures which define different scientific disciplines. I am not claiming that the exercises that have been proposed are in any way definitive: I have no doubt that they can be improved upon and that they might well require extensive modification in the light of practical classroom experience in different teaching circumstances. What I

would like to claim, however, is that although they may be faulty in design they are sound in intention. They are meant to develop in the student an awareness of how English is used to communicative effect in scientific discourse. And whatever exercises in English are devised for students of science and technology their ultimate justification must be the extent to which this intention is realized.

Notes

First published in *RELC Journal* (Singapore), Vol. V No 1, June 1974.