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AUTHOR Cleary, J.
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ABSTRACT

This article presents the subject of English for Specific (or Special) Purposes (ESP) from the point of view of the school teacher or university lecturer attempting to teach science to students for whom the medium of instruction is a second language. The skills a student needs in order to achieve success in a science are analyzed as: (1) discipline-specific--strategies for extracting and patterning the data in a particular field, (2) general organizational--for presenting data in written and iconic form, and (2) linguistic skills. In a second-language situation, the teacher cannot assume that students come equipped with these skills; he must, therefore, teach them in addition to the scientific content of the course. This places constraints on the organization of the course and on the materials that can be used successfully. High-level science materials, such as lectures and lesson notes, modifiable to fit the level of the students' abilities. What seems to be called for is a set of integrated materials which require increasingly complex communication skills and which provide for individualized learning activities. The close cooperation of science and language specialists is needed to produce such materials in many scientific areas. (TL)

INTRODUCTION

THE SUBJECT commonly referred to as English for Specific (or Special) Purposes is currently attracting a great deal of attention in many countries, particularly in the field of science and technology. This edition of ELT Documents presents 3 papers which approach this subject from a different perspective. Two of these record valuable field experience: in one case in an overseas situation (Tabriz), and in the other in Britain (Venezuelans at the University of Essex). The paper by Dr J Cleary presents the EST problem from the scientist's point of view and should give teachers of English an insight into what the head of a science department might ask of the English department. Dr Cleary is both a chemist and an educationist. He has had experience of both the British and American education systems, has taught in both L1 and L2 situations, and has been involved in teacher-training, curriculum development and materials design. His paper, 'Science Teaching in a Second Language Situation', should provide insights for all teachers of English who are teaching science students. It is hoped that all 3 articles will assist those engaged in the design or administration of EST courses.

SCIENCE TEACHING IN A SECOND-LANGUAGE SITUATION – J Cleary

Physics Lecturer:	As a result of this derivation, class, we arrive at the following expression: πr^2.
Student:	No, sir. Pie are round. Cake are square.

1. An overview

THE SCHOOLTEACHER or university lecturer faces a variety of problems in attempting to teach science to a group of students where the medium of instruction is a second language. This paper will present one view of those problems, as seen by the science teacher, and suggest a way of classifying the knowledge and skills areas in which problems seem to arise. The classifications suggested are not hard and fast, nor necessarily mutually exclusive, but appear to be a useful way of viewing the whole problem of learning science in a second-language situation.

A science teacher is confronted by 2 types of problem in teaching students in a second-language situation. First, he faces the problem of students themselves, who are using a second language not only for ordinary communication but also for the more specialised communication demanded by situations in a specific scientific discipline such as chemistry or geology, or in a mixture of disciplines such as chemical engineering, biophysics or [illegible]. In addition, the science teacher has a problem pertaining to the materials which he uses for his teaching and would have the students use to gain access to the knowledge and skills of a subject. Both these problems are complex, whether considered separately or as interacting with one another.

When considering his students, the science teacher is confronted by 2 distinct problem areas. The first is the area of content, the knowledge store of the students, and the second is the area of skills needed for success in the study of a science. The science teacher assumes a certain knowledge store in his students and is concerned with adding to it. In order to achieve this, he must give his students practice in the skills essential both to the acquisition of content and to its appropriate manipulation. Since the acquisition of essential skills is the key to the acquisition of essential content, the chief concern of the present paper will be with those skills.

The skills area, though regarded as a whole in many cases, is here considered as comprising the following types:

1. discipline-specific skills - concerned with data extraction and patterning in a specific field
2. general organisational skills - concerned with general presentation and manipulation of data in many areas
3. linguistic skills

The problem of finding suitable teaching materials is a broad one. Teaching materials are here classified as materials which are open to modification by the lecturer or teacher, such as lectures, lesson notes and independently produced materials, and those which are not open to modification, such as textbooks and journals. But, as will be pointed out, this seemingly clear-cut classification need not be a rigid one.

This paper explores some of the problems arising in teaching students in a second language from the perspectives of the classifications given. It analyses the needs of the student in order to achieve success in a science course and suggests some means of meeting those needs.

II The students

With the advent of taxonomies of educational objectives such as Bloom's classification[1], it has become normal for science educators and lecturers to attempt to present short- and long-term scientific objectives in detail and to indicate skills in specialist fields which students in those fields should be equipped with. Beard[2] summarised one categorisation of skills, which a biochemistry committee utilised for examinations. The list included:

1. recall of specific facts
2. recognition of meaning or implication
3. selection of appropriate generalisations to explain phenomena
4. interpretation of data presented in a variety of forms
5. application of principles to solutions of problems of a familiar type
6. analysis of unfamiliar constellations of events
7. evaluation of a total situation
8. synthesis of data into new and meaningful wholes

A moment's reflection on this list will reveal that, far from being specialist skills only for biochemistry, the hierarchy of skills indicated is in fact applicable to many fields, science and non-science alike. This hierarchy can be further broken down, and each skill can be considered from the perspective of the DISCIPLINE-SPECIFIC, general organisational and linguistic skills involved.

For example, let us consider item 4 from the list above: 'interpretation of data presented in a variety of forms.' Students might be given a reading summarising the treatment of rabbits with coal tar to produce tumours. The reading might include information on the number of rabbits treated and the number of tumours produced under various conditions. Scientific skills involved in the interpretation of the data might be: 1) recognition of trends in the data which indicate accord with hypotheses concerning formation of tumours; 2) assessment of relevance of the data for the support of different theories concerning tumour formation; 3) suggestion of further experiments to be attempted as a result of the data. However, use of these scientific skills would depend on organisational skills which might be necessary for dealing with data in many different fields. Organisational skills useful in the task of interpreting the data in the above situation might include: 1) ability to translate the data from a written account to a simple tabular form; 2) ability to produce a graph of the data, given the variables to be plotted; 3) ability to list the suggested further experiments in a logical order. The patterning skills used may thus be fairly narrow ones in a scientific area, such as deciding whether part of the data is extraneous to a particular theory or fairly broad organisational ones such as production of a table from written data, which is necessary for many fields.* The third area, language skills, is the area in which the science teacher feels least able to cope. What linguistic skills are necessary for students in the situation of interpreting data? Does the student need to be able to recognise meaning in particular clauses, divide sentences into logical and meaningful parts, or organise data into groups of related readings or observations? In short, what language skills are essential to the science student if he is to succeed in the task of interpreting data? Given students who encounter problems in interpreting data, the science teacher tends to feel that what students lack is the ability to relate organised data to a particular theory, when the real problem may lie in their inability to organise the data in a coherent manner in the first place.

The appropriate discipline-specific skills will obviously vary for the different specialist areas, but overall attempts have been made to specify the skills used by a scientist in 'doing science', and the activities associated with 'critical thinking' in science. Consideration of the process skills from a primary science programme on the one hand and an analysis of critical thinking in advanced physics on the other will service to indicate the types of skill necessary at different levels. Science - A Process Approach[4] takes the view that a scientist's behaviour constitutes a complex set of skills which includes the following:

a. observing
b. measuring
c. classifying
d. predicting
e. formulating hypotheses
f. controlling variables
g. interpreting data
h. experimenting

Burke[5] suggests that a person uses such skills as the following in carrying on critical thinking in physics:

1. criticising faulty deductive reasoning
2. recognising what assumptions are to be maintained in drawing inferences from data
3. selecting the hypothesis, from a group of hypotheses, which most adequately explains given data
4. criticising experimental procedures as to the pertinence of the procedure to the problem under consideration
5. recognising the existence and the extent of errors of measurement

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* Cf. the model presented by Jones and Roe on page 35 of their paper[3]. Discipline-specific skills are related to formally learned strategies for extracting and patterning data in a particular field. General organisational skills pertain to their 'general cognitive strategies' and to the patterning of data involved in written and iconic presentations.

However one specifies skills in a particular discipline, they can be seen to be related to the second type of skill outlined above (general organisational skills). For each discipline-specific skill mentioned, there are general organisational skills on which it is based. Making observations of appropriate data is useless if the observations are not carefully and concisely recorded. A chemist may be able to make measurements on a series of reactions and relate the results to a model, but still be unable to communicate his results in a logical manner. A student in physics may recognise the variables which could affect the period of swing of a pendulum, and yet be unable to state how, systematically, to vary them one by one. Thus, success in a particular task depends not only on the particular scientific skills relating to the extraction of data or the perception of patterns of the data but also on the student's proficiency in organising and presenting the patterns he perceives.

In a first-language situation, the lecturer usually assumes that students have some basic organisational skills (though this assumption may not always be correct). His problem then lies in teaching the knowledge and skills peculiar to his field of study, asking the students to employ linguistic and organisational skills as needed. However, in a second-language situation, the science teacher most often cannot assume that students come to him equipped with the necessary organisational skills. Thus, in addition to teaching specific disciplinary skills, the teacher must also give his students practice in basic organisational skills. This added teaching load places certain very real constraints on the disciplinary skills and content which can be presented. If students' organisational skills are at a really basic level, they should be asked to practise specific skills in a discipline and process scientific data only at a correspondingly basic level until their performance shows that they are ready to proceed to a higher level.

In a second-language situation, not only can the science teacher not assume basic organisational skills; very often he cannot even assume basic linguistic skills. This problem places further constraints on the organisation of the science course and on the materials which can be successfully used.

From the students' performance in the classroom, it often appears that either their mastery (memorisation) of content exceeds their skills, disciplines, organisational or linguistic. The result is a general failure on the part of the students in any task requiring more than simple recall of facts. Here it is useful to recognise that students' problems can be attributed to a failure in one or a combination of the areas of skill mentioned. A lack of organisational skills may well prevent him from communicating his findings at all. Thus, in a second-language situation, the science teacher is crucially concerned not only with specific skills and content but also with the training of a broader set of skills upon which the acquisition of disciplinary skills and the processing of scientific content depend.

Gagne[6] has proposed a model of hierarchies of organised intellectual skills which he terms 'learning hierarchies'. A learning hierarchy pertains to an intellectual skill and the lower-level skills that are the prerequisites of this skill. Gagne suggests that if students are asked to perform a high-level task they must possess the prerequisite skills at successive lower levels upon which the high-level skill depends. An analysis of tasks involved in the high-level performance can indicate the prerequisite skills which are necessary. These may be analysed to determine the lower-order skills needed for success in them. This hierarchical analysis may be continued down to a level where the skills are known to be possessed by the students. From this analysis, possible instructional sequences may be proposed. The analysis is valid only in so far as it can be shown that the proposed lower-order skills are actually necessary for the learners in order to learn the higher-order skill.

If students in a second-language situation encounter problems with a particular scientific task, the science teacher may need to analyse the task involved with respect to the types of skill required. Lack of a prerequisite subordinate skill such as language proficiency may be the cause of failure to perform adequately on a higher-order scientific skill. The understanding of a scientific principle may not itself be lacking, but the ability to express understanding is. Recent work in the area of problems of depth-perception in chemistry has also shown the complex interrelationship of scientific, organisation and linguistic skills. Nicholson studied the problems which first-year students at a Nigerian university encountered in understanding depth and spatial relations in 2-dimensional diagrams of framework models similar to those found in chemistry textbooks. University lecturers had had problems with students who could not follow discussions related to the 3-dimensional spatial relations which were represented by the 2-dimensional drawings. From Nicholson's work on this problem, it appeared that successful perception of depth and spatial relations in the diagrams was related to skills in several areas:

a. students' ability to deal with the molecular structure of models (scientific skill)

b. students' ability to understand the organisation of a picture by using the depth cues of the picture

c. students' understanding of words such as 'plane', 'left/right' or 'nearer' when used with reference to a drawing or to the model it represented (linguistic skill)

Consideration of the problem from these aspects enabled suggestions for remedial materials to be made.

III Materials

A second set of problems facing the science teacher in a second-language situation concerns the materials available for use in teaching a science course. Science educators generally agree that equipping students with scientific skills involves more than just lecturing to students and providing them with seminar and laboratory experience[8]. It involves placing students in situations where they can practise their skills to gain access to the knowledge of a particular field and apply that knowledge to the solution of special problems in that field. A key element in providing appropriate practice situations involves finding materials which allow students to practise skills at an appropriate level commensurate with their scientific, organisational and linguistic abilities.

A major concern of the science teacher is that high-level science materials such as university textbooks and journals, which contain important content in a field, are often presented at a level which is inaccessible to students with limited linguistic and organisational skills. Such materials are unmodifiable in that they represent the terminal-skill level which the students must eventually reach. If students are to be competent in a scientific field, their linguistic and organisational skills must be brought up to the level demanded by the literature of the field.

Below are presented excerpts from articles in 2 chemical journals, to give an idea of the literature of one scientific field which students would eventually be expected to cope with:

> Example A: A particularly striking example of the practical advantage which has been taken of the relative unreactivity of solids is the

'molecular packaging' of unsaturated fatty acids, thus protecting them from oxidation by incorporating them in the channels of urea crystals in the form of urea inclusion compounds. Notwithstanding the impression which might be obtained from such examples, reactions believed to occur between molecular crystals and gases have been reported for more than a century. As an example of such a reaction, a picture of a single crystal of 2-naphthol reacting with ammonia is shown in Fig 1. Curiously, certain reactions of great practical value, those of graphite, the ultimate polynuclear aromatic hydrocarbon, with gaseous oxygen, water or hydrogen, as well as the interesting intercalation reactions of graphite with potassium metal vapour or bromine vapour, have been almost totally ignored by the organic chemist[9].

Example B: Saxitoxin is the neurotoxin isolated from toxic Alaska butter clams (Saxidomus giganteus), toxic mussels (Mytilus californianus), and axenic cultures of Gonyaulax catanella. Recently, it was also found to be present in aged extracts of scallops collected during a G. tamarensis bloom. It is among the most toxic substances known, with an LD_{50} of 5-10 g/kg (mouse, ip). The chemistry of saxitoxin has been complicated by its noncrystalline, highly polar, nonvolatile nature, and even the molecular formula has been a subject of debate. As a result of extensive chemical and spectroscopic work, structures 1 and 2 have previously been reported in the literature. We have succeeded in crystallising the p-bromobenzenesulfonate saxitoxin and now wish to report the structure deduced from a single-crystal X-ray diffraction study as 3[10].

Both examples represent a rather distant goal for many second-language science students.

These examples also bring to light another interesting point with regard to the level of skills demanded. This is that, while some technical writings may require equally advanced linguistic, organisational and scientific skills, others might require an advanced level of one type of skill and relatively simple levels of other types. For instance, in terms of scientific content and scientific skills assumed, Example B requires a very high level of proficiency and Example A demands a much lower level. However, in terms of language skills, Example A is extremely difficult and Example B simple and straightforward.

The textbooks of a scientific field are also unmodifiable, though at the beginning the teacher (or institution) has any number of different texts to choose from. Once chosen, however, a textbook cannot be modified and may present problems throughout the course for second-language students unless their linguistic skills can be brought up to the level of the text. The textbook will present the greatest difficulty to second-language students if it is used (as is often the case) as the chief or only source of information and readings which the teacher and students rely upon.

Another problem which may arise with the use of a single textbook is that of 'logical' presentation. Any textbook presents an exposition of concepts which are arranged in what the writer sees as a logical order. This usually means that data, concepts, rules and conclusions are presented step by step. However what is a clearly 'logical' presentation of materials may be psychologically poor from the point of view of the student's assimilation. Ausubel states:

> Probably the greatest damage can be done through neglect in those highly structured areas - such as the physical sciences and mathematics - in which long chains of related ideas or arguments are developed sequentially, each chain in the sequence being dependent upon (often a correlative of) its immediate predecessor... Comprehension fails in such a chain when

for one reason or another, one of the links is not adequately grasped and consolidated. One major reason for the student's failure to consolidate - and therefore to comprehend - derives from a naive confusion (by many instructors) of the 'logic' of the material and the psychology of learning[11].

The point here is that although a textbook presents material in an order which the writer considers logical, some students may not learn easily in the logical way the textbook-writer has set out. As a result, in addition to possible difficulties with the language of the textbook, some students may have difficulty learning material because of the order in which it is presented.

On the other hand, if the science teacher is free to choose and use a number of types of material which can be modified to fit the level of the students' abilities, his chances of achieving success with the students seem far greater, though his problems are by no means over. He can try to control the level of the organisational and linguistic skills demanded of students in learning situations. But in the case of linguistic skills he can do this only in a general way, since he himself is not skilled in the preparation of carefully controlled and graded language-skill practice materials. To succeed here, the science teacher must ask for assistance from language specialists.

More and more, science lecturers are recognising the need to make use of various methods of presenting data at a level appropriate to students' skills, and this is particularly true of the second-language situation. Audiotape/slide sequences, videotape presentations, programmed texts, programmed work-sheets, condensed lecture-notes, films and structural models are examples of modifiable materials which can require a controlled, selected, specific communicative response, or an uncontrolled original response, from students. Content at various levels of difficulty can be presented to students by the methods just listed. The level of skills demanded can and must be modified to accord more closely with the levels of scientific, organisational and linguistic skill which the students possess. Again, the science educator is confronted by a problem he will not solve alone. But recognition of the problem may be the first step towards a solution which can be achieved by the joint efforts of specialists in language and science.

IV Needs and means

Given the above problems pertaining, first, to the second-language science students themselves, and secondly to the materials available to the science teacher, what are the needs of science teachers in a second-language situation, and what means can be found to meet these needs?

First, the science teacher needs to help the students to develop an integrated body of background knowledge consisting of meaningful scientific concepts and principles which are systematically related. Then he must help them to develop a set of skills with which they can operate on their background knowledge and acquire new knowledge which can be integrated into the existing cognitive structure. This implies placing students in situations where they are asked to use the skills they possess and in doing so develop these skills further. Students need to be able to obtain new knowledge from any appropriate source; they need to be able to communicate the knowledge they possess; and they need to be able to combine their existing knowledge with new knowledge to solve problems in their field.

As for the problem of materials, students need practice in reading - everything from textbooks and lecture-notes to tables, diagrams, articles and reviews - at an appropriate science-content level. They need practice in listening - to lectures, slide/tape sequences, audiotapes, videotapes and the comments of other students in discussions on appropriate science content. They need practice in writing and discussion in situations characteristic of those in which a scientist finds himself: producing and discussing reports and articles, presenting short seminars, working on problems and producing written solutions, engaging in simulated activities, summarising literature articles and constructively criticising data, hypotheses, theories and research findings.

From the science teacher's point of view, this does not mean practising those skills on isolated bits of content nor practising scientific skills apart from organisational or linguistic skills. Whether it is a first-year university student writing a biology report on the comparison of several different types of cell or a research-worker engaged in writing the results of a series of experiments on a new enzyme, the skills employed are not isolated as scientific or organisational or linguistic skills. They are used simultaneously, and in the learning situation they should be practised simultaneously at a level commensurate with the student's degree of proficiency. This, of course, assumes that the student's level of proficiency is constantly being raised through controlled practice.

What seems to be called for is a set of integrated materials which require increasingly complex communication skills. At a beginning level, relatively simple scientific concepts and skills must be accompanied by similarly simple organisational and linguistic skills practised in the context of a significant scientific task. The student should be mainly conscious of developing scientific skills. In order to succeed in the scientific task, he must use the organisational and linguistic skills, but without necessarily being aware that he is using them. Within the set of integrated materials, provision should be made for individualised learning activities, since not all students will be at the same level of proficiency, especially at the beginning of a course. The existence of individualised learning activities also means that different routes may be followed in the development of essential skills. Where one student might read several chapters of a textbook, another might see and listen to a tape/slide sequence and then read a programmed text related to the textbook chapters. In this way individual students can use materials which are best suited to their learning needs.

A science teacher's goal is to produce students who are competent in a given discipline. The means he uses will largely determine whether or not he will succeed. The ideal means suggested here involve an integrated programme of materials. But at present such a programme, involving the development of scientific, linguistic and organisational skills, is not available to most teachers in different scientific disciplines. To produce materials in many scientific areas, the close cooperation of science and language specialists working together in those areas is needed. Only then will the science teacher's problems with materials and students in a second-language situation begin to be solved.

9

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