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# Science and language: a new look at some old issues

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*This article is an edited version of a paper presented as part of a panel discussion on the role of language in academic achievement at the 1988 Academic Support Programme (ASP) Conference at the University of Cape Town. It was a response to a paper which had been distributed to panelists and participants, who were asked to respond to the central themes and to the use of Cummins's framework for conceptualising language proficiency. Although not directly acknowledging its debt to Cummins, the paper drew significantly on his conceptualisations. This article also relates developments within the Academic Support Programme at the University of the Witwatersrand in the area of science and language to constructs developed by Cummins, and questions the helpfulness of some theoretical developments in applied linguistics in terms of the South African education system.*
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## INTRODUCTION

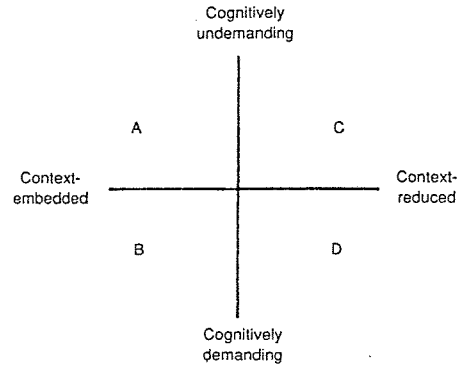
Cummins (1984) has proposed an approach to understanding language proficiency and its role in academic achievement which is grounded in the notion of two intersecting continua. His framework grows out of the tradition of research into bilingual education in North America particularly, and has been developed in response to the specific situation prevailing there. Macdonald's paper is of interest as it demonstrates the applicability of Cummins' framework to the South African educational context, specifically to that section of the schooling system which has traditionally fallen under the control of the Department of Education and Training (DET). The framework is of interest to those of us working at tertiary level with students coming out of this system and who are often referred to as "underprepared" for university study. These students are often characterised as having "language problems". They are also frequently identified as having "conceptual" problems. In both areas, there is a lack of consensus as to the nature of these language and conceptual problems and how to respond to them. I would suggest that the conceptualisation of language proficiency outlined below enables us to better answer some of the questions that have engaged those working in the academic support field. It helps us to a clearer understanding of the specific types of "language" skills required by university learning and the possible effects of the schooling system on the acquisition of these skills.

One of the continua proposed by Cummins relates to the range of contextual support available for expressing or receiving meaning. The extremes of this continuum are described in terms of "context-embedded" versus "context-reduced" communication. Context-embedded communication occurs when the participants actively negotiate meaning, usually in a face-to-face situation. The opportunities for immediate feedback to clarify meaning in context are evident. Context-embedded communication derives from interpersonal involvement in a shared reality which does away with the need for explicit linguistic elaboration of the message. Context-reduced communication, on the other hand, relies primarily on linguistic cues to meaning. A shared reality cannot be assumed and the language used must therefore be elaborated precisely and explicitly to minimise the risk of misinterpretation. While everyday interpersonal communication tends to be of the context-embedded variety, classroom/lecture communication and written academic communication, in particular, tend to be of the context-reduced type.

Cummins proposes that the problems that beset our understanding of the role of language in academic achievement, particularly where bilingual speakers are concerned, can better be understood by viewing this continuum as intersecting with another which addresses the degree of active cognitive involvement in the task or activity. The two poles of this continuum are "cognitively demanding" versus "cognitively undemanding". Tasks are viewed as cognitively more or less demanding in terms of the amount of information that must be processed simultaneously by the individual in order to carry out an activity. The upper part of this continuum consists of communicative tasks in which the linguistic tools have become largely automatised and thus require little cognitive involvement for appropriate performance. Tasks at the lower end of the continuum have not become automatised and therefore require active cognitive involvement. The intersection of these two continua provides us with a framework within which to examine language proficiency that can be represented as in Figure 1.

Thus language proficiency is conceived of in terms of the underlying contextual and cognitive dimensions. Skills that fall into quadrant A are classified as cognitively undemanding and context-embedded and have been called basic interpersonal communicative skills (BICS). Quadrant D however characterises what has been called cognitive-academic language profi-

*Figure 1*
*Range of contextual support and degree of cognitive involvement in communicative activities*



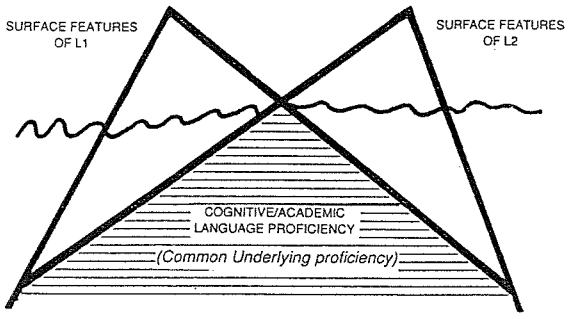

*(Cummins: 1984)*

ciency (CALP) where the task is cognitively demanding and the context reduced. Persuading someone that your point of view is correct is an example of a quadrant B skill, while writing an essay is quadrant D skill. BICS-type skills can develop outside the classroom but CALP-type skills seem to need a classroom type of environment to develop. The typical university academic skills fall within this quadrant.

Another aspect of Cummins's research that is relevant to the issues under discussion is what he has called the "interdependence hypothesis" which has been stated formally as follows (Cummins 1984: 29): "To the extent that instruction in language (L)x is effective in promoting proficiency in Lx, transfer of this proficiency to Ly will occur provided there is adequate exposure to Ly (either in school or environment) and adequate motivation to learn Ly".

This hypothesis allows for the conceptualisation of the developmental interrelationship between first-language (L1) and second-language (L2) proficiencies. Some aspects of L1 and L2 proficiency, particularly CALP skills, are viewed as being interdependent, and are seen as manifestations of a common underlying proficiency which is theoretically capable of being developed through instruction in either language. Macdonald suggests, on the basis of this principle, that promoting Setswana CALP will lead to enhanced English CALP. The "dual-iceberg" model of bilingual proficiency is represented below:

*Figure 2*
*The 'dual-iceberg' representation of bilingual proficiency*




*(Cummins: 1984)*

## LANGUAGE AND SCIENCE AT SCHOOL

### Schooling, language medium and Cummins's framework

Macdonald contrasts a Standard 2 and a Standard 3 class in a Bophuthatswana school. The Standard 2 class is taught through the medium of the first language (Setswana), the other through the medium of English which is the second language (EL2) and medium of instruction from Standard 3 (the fifth year of schooling) onwards. In the former, she witnesses a highly successful lesson — the children are learning in their L1; in the latter group, which was taught by the same teacher the year before, there appears to be little meaningful learning taking place. Macdonald points out that the first group has an excellent teacher but she emphasises the disruption of the learning process that occurs with the switch to EL2 as medium of instruction.

It seems that the disparity between English "taught as subject" and English as medium of instruction is vast. Macdonald points to major jumps in vocabulary, grammar and concepts from Standards 2 to 3. In Standard 3, pupils encounter textbooks for the first time, vocabulary increases, sentence structures become more complex and new ideas increase in volume (ten subjects are now studied through the medium of English). She suggests that the English course up to Standard 2 prepares pupils for BICS (context-embedded and cognitively undemanding), not CALP (typical subject classroom) type skills. She provides examples from science and other textbooks in which she has found both the language and the conceptual content to be too difficult for Standard 3 pupils.

What is also suggested is that, at present, CALP in the first language is barely developed and is largely allowed to atrophy after the first four years of schooling in DET schools. ( The L1 is no longer officially used as the medium of instruction although we know that many teachers resort to it, further complicating the situation.) However, as the interdependence principle suggests that the development of L2 proficiency is at least partially dependent on the development of L1 proficiency, pupils would benefit from the promotion of CALP skills in the L1. L1 language study at school should be directed towards the cognitive demands of the curriculum which is not the case at present. Aspects such as the understanding of concepts, critical thinking skills, and inferencing skills are important and could be taught in L1. While it does appear possible for students to acquire CALP skills solely through the L2, the task is a more difficult one, and is facilitated if these skills are acquired initially in the L1.

Macdonald suggests strongly that many of the learning problems that persist throughout the child's schooling can be traced to the fundamental disruption that occurs with the switch of medium as outlined above and the difficulties that surround the acquisition of CALP skills. It should be noted that the changes in language policy regarding medium of instruction that were heralded by the introduction of "bantu education" in 1953 have added to the complexity of the educational scenario. The reduction of the role of English as medium was a key element of this policy. Amongst other outcomes, the English language proficiency of at least two generations of teachers has been affected. Societal segregation, in conjunc-

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tion with inferior education, has also played a role in the emergence of non-standard forms of English which do not facilitate communication. This situation is reflected in the matriculation results of the DET. Hartshorne (1985), referring to the 1983 results, states that "even in English (Second Language Higher Grade), the medium of instruction and general tool of communication, only 36% gained a pass. There is no question but that declining standards in English are significantly affecting black pupils' capacity to cope with other key school subjects". The perception that inadequate language proficiency is a major problem in teaching and learning is widespread. What is not clearly understood are the reasons for this "linguistic failure". A letter from a lecturer at a College of Education in Bophuthatswana (Matlhasedi 1988) highlights this perception:

> It is absurd to find that a good teacher cannot impart information successfully because of language incompetence. Students or pupils fail to understand the subject matter clearly because the teacher cannot explain or express himself effectively. Take, for instance, a science teacher with all the necessary information becoming frustrated in front of his class as a result of his inadequacy in language use. He fails to transfer the important information he acquired and eventually the students or pupils lose confidence in him.

"Linguistic competence", thus, cannot be separated from the cognitive demands of the task. The role of language in academic achievement is such that it becomes difficult to understand how a teacher can have "all the necessary information" and lack the academic language skills necessary for its transmission.

## Science teaching in DET schools

The poor quality of science teaching in DET schools is fairly well-documented and the matriculation results bear testimony to this. Hartshorne (1985) says of the 1983 DET results: "only 3,6% of the total Standard 10 entry gained a pass in Higher Grade Mathematics and 2,7% in Higher Grade Physical Science". More recent figures reveal little change. In 1987, in the Johannesburg circuit of the DET, of the 1 558 who wrote Higher Grade Mathematics, only 41 (2,6%) passed, while of the 601 who wrote Higher Grade Physical Science, only 24 (3,9%) passed. Only 14 and 8, respectively, passed Mathematics and Science with at least a "D" symbol (Hofmeyr & Spence 1989).

It would appear that inadequately trained teachers and the lack of facilities are the chief causes of poor pupil performance, with the language situation being a complicating factor. In a survey of matriculation pupils in rural Natal DET schools the lack of laboratories and scientific apparatus was perceived as one of the main reasons for failure. Other perceived causes of failure were unqualified teachers and unfair exam marking, while many students blamed themselves (Simon & Beard 1985).

Classroom discourse recorded by Muller (undated mimeo) provides us with an insight into the type of teaching that predominates in DET schools. He stresses that the pattern of the lesson was in no way unusual for this school or any other black elementary school that he investigated. The extract below is from a maths lesson to a class in the second-last year of junior school, the first year in which the students at this particular school received instruction in English.

T: What is a graph, class? What is a graph?

(No response)

T: (reading from notes) A graph is a diagrammatic representation illustrating a connection. (Writes this on board). What is a graph, class?

S's: (in unison, haltingly) A graph is a diagrammatic representation illustrating a connection.

T: Again

S's: A graph is a diagrammatic representation illustrating a connection

T: Again

S's: A graph is a diagrammatic representation illustrating a connection

T: Boys

S's: (boys) A graph is ... (etc.)

T: Girls

(Etc. Teacher asks back row, middle row, front row and all together. This proceeds for ten full minutes. T rubs statement off board.)

T: All right, class, what is a graph?

S's: (Unison, loudly) A graph is a diagrammatic representation illustrating a connection.

T: Good

It is doubtful whether this type of teaching and learning will equip pupils to cope with the CALP-type demands of university study. In fact, students who are unable to understand either the language being used or the concepts being taught are forced into a rote-learning mode and are not practising the important quadrant D skills. Furthermore, in terms of a taxonomy of cognitive skills commonly practised in the science classroom developed in Australia, the factual recall practised in this type of lesson rates very low (see Table 1 below, Hacker 1984). More empirical research is needed in this area but the data summarised in this paper indicate that the higher-order skills are rarely practised in DET schools, even in the senior classes.

*Table 1*
*The Intellectual Ability Being Practised in the Science Classroom*

1. Acquiring, recalling, or confirming facts
2. Delineating scientific concepts, principles, or theoretical models
3. Identifying problems
4. Solving concrete problems
5. Solving problems by applying scientific concepts, principles or models
6. Making or testing hypothesis or speculation
7. Identifying or describing apparatus, equipment, or materials
8. Describing or practising conventional experimental procedures
9. Designing novel experimental procedures
10. Making, describing, or recording observations
11. Interpreting observed or recorded data
12. Inferring from observed or recorded data

*(After Hacker: 1984)*

Bradley *et al* (1985) refer to the prevalence of pre-existing scientific misconceptions (alternative conceptions) amongst all students studying Chemistry, but suggest that these problems are exacerbated amongst DET students due to inferior schooling.

Furthermore, it is important to note that scientific discourse is not well-established in the vernacular languages of South Africa. The possibilities of establishing CALP in the L1 are therefore obviously reduced and the task of so doing in English all the more essential. Connelly's (1988) comparison of Tanzanian and South African responses is germane:

> At present the Bantu mother-tongues of South Africa are not well developed for conveying concepts of mathematics and science in the primary and secondary school. This is likely to be a temporary phenomenon and is not an intrinsic element of the languages concerned. Swahili, for example, has developed the capacity to accommodate key concepts in a very short period of time — but this is because there are large numbers of science and technology teachers in Tanzania consciously developing the necessary terms: a situation which does not yet exist in Southern Africa.

## APPLIED LINGUISTICS: LANGUAGE AND SCIENCE

This section of the article draws on the experience of the ASP at the University of the Witwatersrand in developing a language and communication course for Engineering students. It attempts to understand how the specificity of the South African educational context results in textbooks and course materials produced elsewhere for English Foreign Language/English Second Language students being largely inappropriate for the students attending the ASP and suggests a more appropriate pedagogical response.

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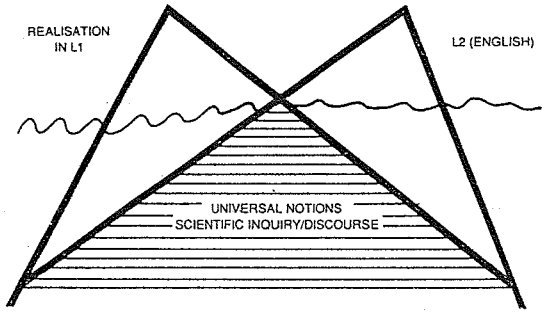
### Some developments

One of the most influential theorists in this area has been the British applied linguist, Henry Widdowson, who has emphasised the essential nature of language as communication. Much of his work and the development of the theoretical bases for it has been in the field of EST. From the late 1970s onwards he (and his colleagues) formulated a coherent approach to understanding scientific discourse which is summed up as follows (Widdowson 1979): scientific discourse can be seen as a set of rhetorical acts like giving instructions, defining, classifying, exemplifying and so on, but the manner in which these acts are related one with the other and the manner in which they are linguistically realised may be restricted by accepted convention; 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 realise it; the student entering higher education will have already been initiated into these concepts and procedures as they are realised through his own language and through non-verbal symbolisation. 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 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. Widdowson's understanding of the relationship between science and language can therefore be represented in very much the same way as Cummins's interdependence hypothesis:

*Figure 3*
*The 'dual-iceberg' view of the relationship between language and science*




I would argue that the Widdowsonian approach, which I shall label a "translation" approach, as it is based on "translating" into English the knowledge the student is already presumed to have in the L1, is not adequate in our context. The interdependence principle suggests that the promotion of L1 CALP will enhance L2 CALP. In South Africa, this does not appear to be happening, essentially for the reasons outlined so far. The early switch to English-medium instruction, with CALP not established in the L1, impedes the ability to study subjects like science in the L2. With the transition to the EL2 medium of instruction frequently occurring in the rather brutal manner described by Macdonald, CALP is not being well-established in English either. Moreover, science is not being taught in the L1 at all, so it becomes difficult to adopt a "translation" approach. Switching to the vernacular in the classroom does occur, especially when teachers are L2 speakers themselves and this further confounds things. A situation has developed in schools in which science is being taught in English by teachers who are not adequately qualified in language or content, and whose academic literacy is not well-established in the L1 or English. Finally, the type of science being taught is not as Widdowson defines it: it is far from clear that the student "will have already been initiated into these concepts and procedures as they are realised through his own language". At tertiary level, an immediate consequence of this is that few assumptions can be made about students' scientific knowledge or their language proficiency.

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Many EST course books aimed at tertiary level students have been developed based on Widdowson's approach. As would be expected, they focus on the "language" needs of students. The statement below is fairly typical of the methodology in use. The Teacher's Guide to *English for Study Purposes* (Smith & Coffey 1982) states that the course is: "a language course and not a science course ... . The students' respect stems from their [the teachers'] knowledge of the language not the topic". The course assumes that "topics and scientific content will be familiar [to the student] but that the language will be fresh and new".

The Teacher's Guide to *Nucleus* (Dudley-Evans *et al* 1978) (an earlier series) states that "the level of the engineering content is not high and the teacher should not be intimidated by it. The aim is to interest the student with relevant material and allow him to practise language items in the contexts in which he is most likely to meet them. Most of the content should be familiar or readily understandable to the student. ... The teacher should not be worried about making a mistake or about not understanding an engineering reference which may come up in class. The students are studying engineering and a situation where they have to explain a point to the teacher is a very valuable communicative exercise".

On the basis of the argument outlined above, it becomes clear that materials of this sort assume that students have a reasonably well-developed "scientific competence". In accordance with the Widdowsonian analysis of the role of language, students are presumed to "lack" the surface level language skills in the L2 (English) which the language teacher can then easily impart. However, in our context, it is far from clear that students are in possession of either the underlying science skills or the language skills. Neither can be assumed. This is not to imply in any way that the students are in some sense "deficient". The issue that needs addressing, for those in ASP, is how to respond to students' learning needs.

## A language and communications course

In developing a language and communications (LC) course for Engineering students who are EL2 speakers on an Academic Support curriculum, it quickly became apparent that course books designed for students of EST were not directly usable in our context. Although, in some instances, approaches and methodologies were appropriate, the materials could not be used without substantial reworking of both contents and skills. While part of the difficulty is attributable to student reluctance to engage with any materials that are perceived as not directly relevant to them "as engineers", there are other factors at work.

In the initial conceptualisation of the LC course, it was decided to appoint a "language specialist" with ESL expertise. From the outset, the decision was made to contextualise as far as possible the requisite language skills within an engineering framework (Kotecha 1987). The passages quoted above from two representative course books would seem to indicate that the language tutor's task was a feasible one. However, being based essentially on the Widdowsonian analysis as outlined above, these textbooks are unable to respond to the specific problems engendered by both the inadequate scientific competence and the poor academic literacy skills of students entering tertiary education.

The EST teacher in our context is frequently called upon to explain scientific/engineering concepts within the texts selected for LC work and is mostly unable to do so. This had led to the adoption of a team-teaching approach to the LC course which is proving extremely fruitful. A physicist who is qualified in Engineering is presently collaborating with the language specialist in designing materials and teaching the course. Johns' and Dudley-Evans' (1985) remarks on team-teaching although applicable to "overseas" students studying in Britain, seem appropriate here: "Failure ... is rarely attributable to 'knowledge of the subject' or 'knowledge of the language alone' for 'these factors are inextricably intertwined'". The complex nature of the acquisition of language and science skills by South African EL2 students during their schooling adds a further dimension to these remarks. Contextualisation becomes not merely a response to the absence of relevance and "authenticity" in the materials but an attempt to further embed language in the reality of students' mainstream course content, thereby reducing the cognitive demands on them.

Whereas Johns and Dudley-Evans worked with a team made up of a course lecturer and the language tutor who collaborated from time to time, in the LC course the subject specialist and the language tutor are together in the classroom and at all stages of the planning process. Our experience to date leads us to believe that, particularly in the sciences, a team-teaching approach to cognitive academic language skills is essential. Team-teaching is an unexplored area in ASP and in South African education generally. It is, as has been pointed out, somewhat more expensive, and dependent to a large extent on the "chemistry" between individuals. In situations where there is a strong likelihood of the subject specialist acquiring the language skills as a result of the constant interaction with the language tutor, these tutors may at some future stage be able to work independently of the language tutor. The converse is also a possibility, but seems less likely, and will depend on the extent to which the curriculum in the mainstream varies from year to year and how closely the language course is tied to this syllabus. As an andragogical response to the specific educational effects of the DET, and the nature of the language problems which students from this system display, it is a response which seems worth pursuing.

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