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RESEARCH REPORT (EMPIRICAL STUDY)
Methods and issues of teaching and learning

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LEARNING SCIENCE THROUGH ENGLISH: AN INVESTIGATION OF THE VOCABULARY SKILLS OF NATIVE AND NON-NATIVE ENGLISH SPEAKERS IN INTERNATIONAL SCHOOLS

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ABSTRACT: This paper describes a study carried out at nine international schools in Europe and Asia, to investigate the command of non-technical vocabulary amongst native and non-native speakers of English. A total of 758 pupils participated in the study. Data were collected using multiple-choice tests designed and administered in the early 1980s in a large sample of schools in Great Britain to test secondary school pupil's command of ninety difficult non-technical terms. In this paper, our data are compared with the British sample and the findings are set in the context of theories relating to English as a Second Language (ESL) learning. Non-native speakers attending the schools in the study sample show a deficit in their command of non-technical vocabulary, compared to their native speaking counterparts, amounting to about two years at each grade level tested. Native speakers surpass or equal their counterparts in the original British study. [*Chem. Educ. Res. Pract.*: 2003, *4*, 233-247]

KEY WORDS: *vocabulary skills; scientific literacy; non-technical terms; English as a Second Language; International schools; second language learners*

INTRODUCTION

Science teachers are becoming increasingly aware of the importance of language in the classroom. The language of science is difficult and often obscure, even for native speakers. It requires careful and precise explanation in order to ensure a shared meaning between the participants in classroom discourse. Communication in science relies heavily on context reduced (where meaning is provided by purely linguistic cues), cognitively demanding language, which has been identified as being particularly difficult for second language learners to acquire (Cummins, 1980). The academic success of second language students in school subjects is more closely related to this type of proficiency (Cognitive Academic Language Proficiency or CALP) (Chamont & O'Malley, 1987) than the more easily acquired Basic Interpersonal Communication Skills (BICS). At the same time, research in second language acquisition has led to the development of an approach known as Content Area Instruction (Dodson, 1985; Shih, 1986; Lykke, 1987; Green & Slater, 1988; Reilly, 1988; Crandall et. al. 1987; Crandall & Tucker, 1989), which has been widely adopted as an element of English as a Second Language (ESL) instruction in international schools. The success of content area instruction can be attributed to the fact that it is likely to contribute specifically to the development of CALP (Krashen, 1981).

A number of aspects of science make it an ideal medium for learning language especially in helping to reduce the affective barriers for L2 pupils (Palma & Myer, 1988; Crandall & Tucker, 1989), whose primary language is not English. Science activities reduce learner anxiety, increase self-confidence, are motivational and require a high level of participation and interaction.

It follows that, from the point of view of the science teacher dealing with non-native speakers, some of the prerequisites for effective language instruction are present in the nature of the subject. The challenge for science teachers is to make use of the potential in science lessons for providing a rich context in which to learn the language of science. This will not happen automatically and, as Wellington and Osborne (2001) point out, the science teacher needs to give prominence to language by employing a range of strategies and pedagogical devices.

Non-technical vocabulary presents a particular problem for science teaching in a mixed class of native and non-native speakers. These are terms that have one or several meanings in an everyday setting but have a specific and sometimes different meaning or connotation in a scientific context. Examples include words such as 'control' when used in reference to an experiment and 'dominant' when used in genetics (dominant gene) or ecology (dominant species). While new technical terms will be unfamiliar to both language groups, native speakers can be expected to have a better command of a range of meanings for non-technical terms and to be able to use these words in a range of different contexts.

THE PRESENT STUDY: DESIGN AND ADMINISTRATION

In the early 1980s, Cassels and Johnstone (referred to here as the C&J study) investigated the ability of secondary school pupils in Britain to understand and interpret certain carefully chosen non-technical terms that were deemed to be important in science (Cassels & Johnstone, 1980, 1985). This work has proved to be a valuable contribution to the development of remedial strategies aimed at combating the language problem in science. A total of ninety words were examined in the original study. Each word was tested in four types of multiple-choice question (formats) as follows:

Format a:	A one-word synonym with no context.
Format b:	The word is placed in four everyday situations, only one of which is correct.
Format c:	The word appears in a science context stem.
Format d:	The word appears in a non-science context stem.

The details of the experimental design as well as the text of the tests can be found in the original paper (Cassels & Johnstone, 1985). The ninety test-words were divided into two 45-question tests labeled Package A and B, within which the formats were scrambled to produce four test versions labeled pink, green, blue and yellow.

The interest in this particular study is that one of the authors (FJOF) teaches science in an International School and wanted to see what influence language had on learning in science for students whose first language was not English. International Schools, with their rich mix of nationalities and languages, provide a unique laboratory to investigate problems of language in learning science for native and non-native English speakers (Lynch, 1985; Meakin, 1987). The study and the results should also be of wider interest with the increasingly multi-lingual backgrounds in many schools in English-speaking countries (Spolsky, 1985; Rosenthal, 1995).

For the purpose of the present study, the Cassels and Johnstone tests were administered at nine international schools in Europe and Asia. Some characteristics of the participating schools are summarized in Table 1. The language of instruction in all cases is

TABLE 1: *Summary of statistics for the nine participating schools.*

School	Number of students	M:F ratio	NN:N ratio	Principal Languages
1	124	48:86	76:58	English, Japanese
2	26	15:11	24:2	Japanese, Hebrew
3	36	18:18	10:26	English, French
4	46	28:18	20:26	English, Dutch
5	65	65:0	37:28	English, Japanese
6	46	22:24	31:15	English, Japanese, German
7	67	31:36	40:27	English, Dutch
8	291	156:135	159:132	English, Japanese, Chinese
9	47	19:28	33:14	Japanese, English, French
Tot.	758	1:0.88	1:0.76	

M:F = male to female ratio
NN:N = non-native to native English speaking ratio

English. The principal native language represented amongst the sample population includes English in all but one case with Japanese also well represented. All of the participating schools are accredited to the European Council of International Schools and in that sense the educational systems employed are comparable.

The language backgrounds of the students in this sample are summarized in Tables 2 and 3. Bilinguals with English as their second language (L2) were classified as non-native speakers even if they purported to be able to communicate equally well in English and in the native tongue. In most of these cases English was not the language spoken at home.

Table 2 lists the native languages of the non-native English speakers in the sample. Thirty languages are represented in all, making up 57% of the sample. The native English speakers making up the remaining 43% are divided roughly equally into monolinguals and bilinguals as shown in Table 3.

There is a large difference in sample size between the present study (9 schools, 758 pupils) and the C&J study (200 schools, 30,000 pupils). However, the network of International Schools provides a unique forum for investigating the effect of non-native English speakers who are learning together with native speakers in English.

TABLE 2: *Best languages in the nine-school sample.*

Language	Number of students	Language	Number of students
Arabic	2	Nepali	2
Bengali	5	Norwegian	2
Bulgarian	2	Persian	2
Chinese	41	Portuguese	5
Danish	4	Pushtu	1
Dutch	23	Russian	2
Finish	11	Serbo-Croatian	6
Flemish	2	Spanish	6
French	18	Swedish	15
German	25	Tamil	3
Hebrew	13	Thai	23
Hindi	9	Turkish	4
Hungarian	1	Urdu	3
Indonesian	4		
Italian	3	Non-native Total	430
Japanese	171	Native English	328
Korean	22	Total	758

TABLE 3: *Language categories in the nine-school sample.*

Language category	Number of students	%
Monolingual, English	152	20.1
Bilingual, Native English	176	23.2
Bilingual, Native Other	223	29.4
Bilingual, No English	23	3.1
Monolingual, Other	184	24.2
Total	758	100

STABILITY OF THE SAMPLING

The first five questions in each of the eight test versions (pink, green, blue and yellow) are identical thus acting as controls and allowing the stability of the sampling to be gauged. In the C&J study the facility values (% correct responses) for the first five questions were found to be significantly different in less than one case in ten. Table 4 below shows the data for the present study.

In no case are test variety differences significant (using the Student's *t*-test) at $p = 0.5$ and in six out of ten comparisons they are not significant at $p = 0.9$. Thus, despite the small sample size and the diversity amongst the participating schools, it can be claimed with reasonable confidence that the differences in facility values for the test questions may be attributed to the supposed causal factors rather than to bias in the sampling.

TABLE 4: Facility values for questions 1 to 5 by test version.

Question	A Pink	A Green	A Blue	A Yellow
Q1	91	90	83	80
Q2	91	92	82	94
Q3	91	92	83	89
Q4	72	70	76	72
Q5	96	98	95	94
	B Pink	**B Green**	**B Blue**	**B Yellow**
Q1	89	83	81	85
Q2	91	86	87	87
Q3	94	90	88	89
Q4	79	75	70	68
Q5	98	99	97	96

ANALYSIS

In the following analysis comparisons are made between native speakers (including monolinguals and bilinguals with their first language, L1, as English) and non-native speakers (including bilinguals with L1 not English and monolinguals with L1 not English). Where appropriate, the results for the present study are compared with summary data from the C&J study. The data are examined under the headings:

1. Question format
2. Year group
3. Weakest words
4. Words needing special attention
5. Word register

1. Question format: One of the aims of the C&J study was to establish whether the format in which a given word was tested played a role in the ability of secondary school pupils to use and/or recognize the meaning of the word. No clear pattern was found regarding the relative difficulty of the four formats tested. However, many of the very weak responses occurred in format a. Figure 1 below shows that this format is indeed weakest when the pooled average facility values for Y5 to Y7 are considered. Format a is also the weakest format for native speakers in the present study with a facility value of less than 50% for about half of the test words. Amongst non-native speakers, format b is even weaker with facility values of less than 50% for more than two thirds of the words.

Figure 2 shows the pattern of performance, by format and year, for the C&J study. Variation in performance on the four formats is strongest in Y5.

Figures 3 and 4 show the breakdown for native and non-native portions of the present sample. Variation by format is greatest amongst non-native speakers, particularly in grade 10. There is a clear, if weak, trend of improvement among the four formats in the sequence: a < b < c < d, with a and b being particularly weak among non-native speakers and b being the weakest format in grade 10.

This leads to the conclusion that stating the meaning of a word out of context, i.e. finding a synonym or identifying correct usage, is more difficult than recognizing meaning in a given context, especially for non-native speakers and in particular for younger students. Given the trends apparent in Figures 4 and 5, it appears that recognizing meaning in an

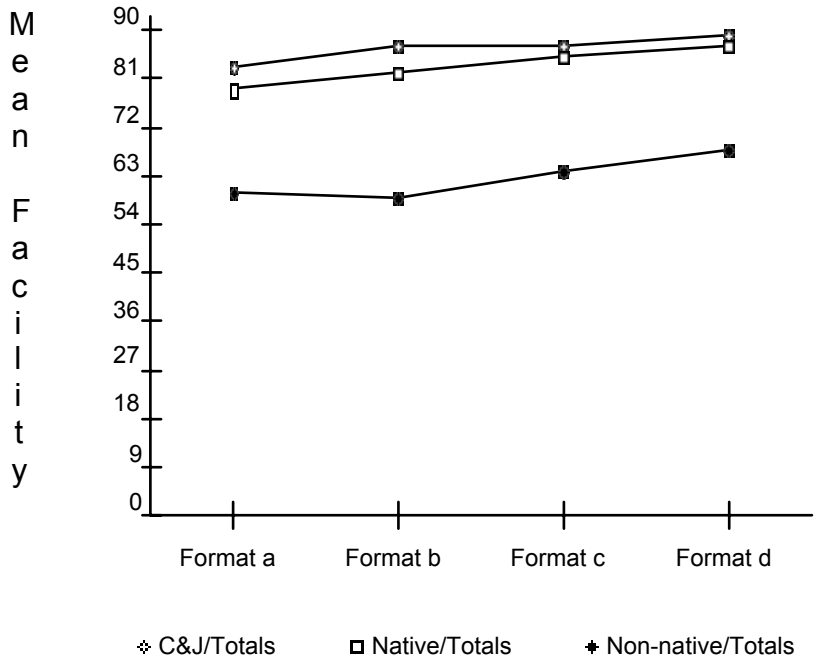

FIGURE 1: *Format means (pooled for Y5, Y6 and Y7) for the C&J study and (pooled for grade 10,11 and 12) in the present study.*

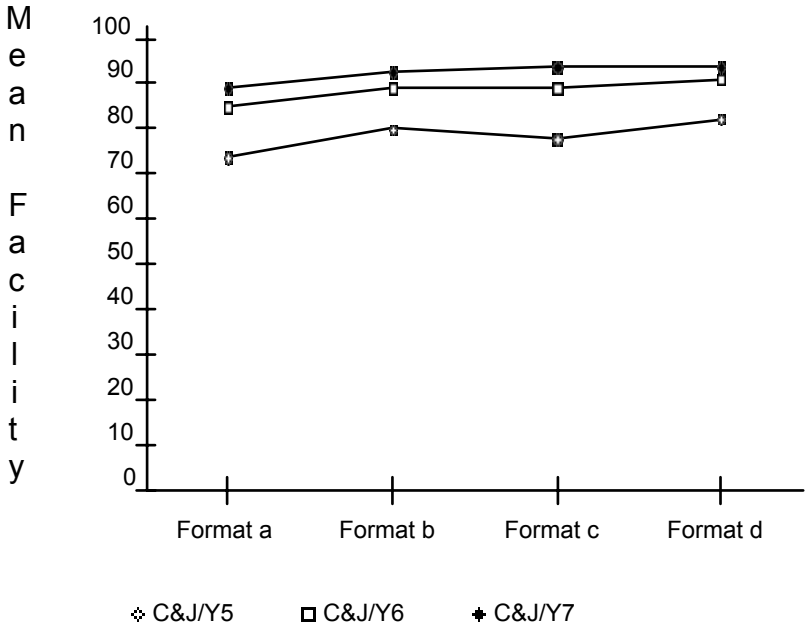

FIGURE 2: *Comparison of the format means in the three final years of the C&J study.*

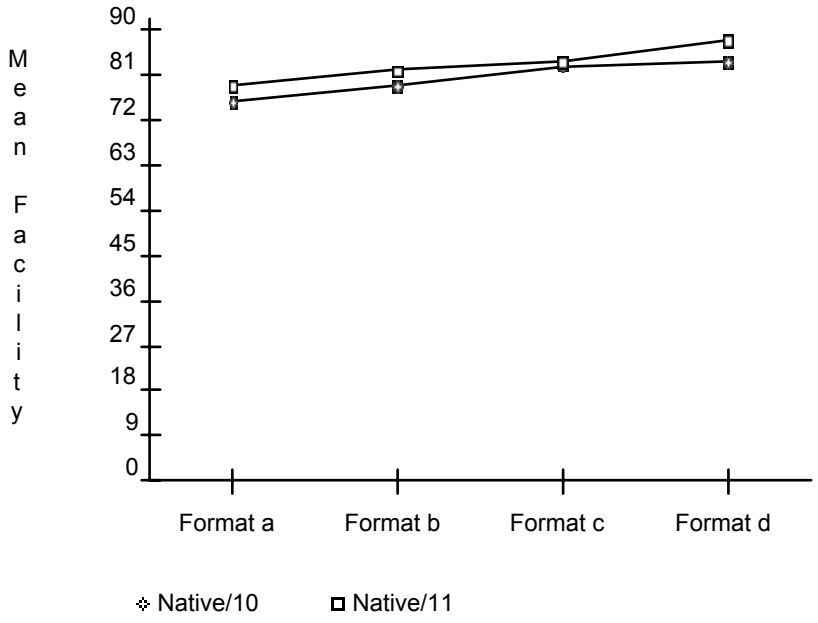

FIGURE 3: *Format means for grade 10 and 11, native speakers in the present study.*

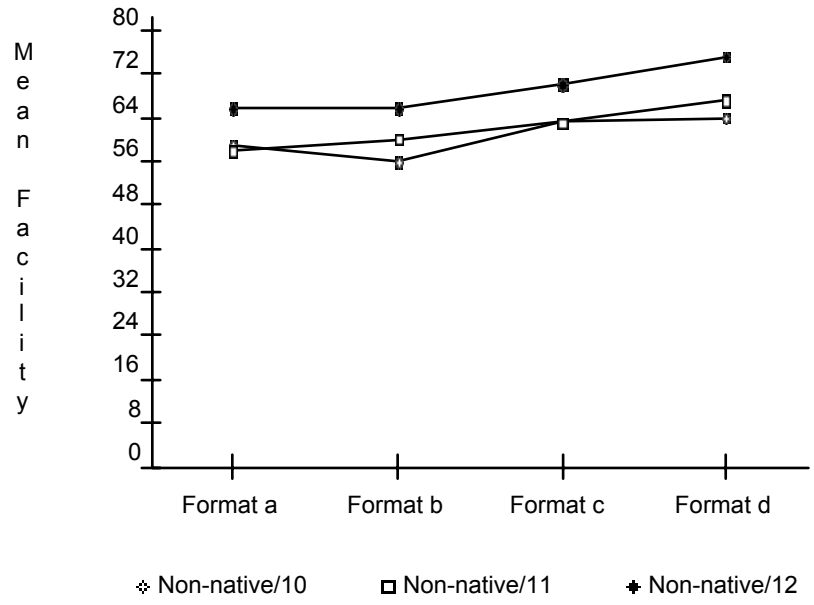

FIGURE 4: *Format means for grades 10, 11 and 12, non-native speakers, in the present study.*

everyday context is easier than in a scientific context, although the differences here are not statistically significant.

2. Year groups (grade): The trend of improvement by grade noted by Cassels and Johnstone, in terms of the proportion of words mastered by each year group, is also apparent in this study (Figure 5). For native speakers, the differences between the corresponding year groups in the two studies are not great, and are almost identical for the two oldest groups. Grade 10 native speakers performed considerably better than their Y5 counterparts by this criterion. This may be a reflection of the fairly uniformly high socio-economic status anticipated in an international school setting - a factor identified by Cassels and Johnstone (1980) as being important for the ability of secondary school pupils to answer multiple-choice questions. It may also be a result of the fact that the C&J sample is not controlled for language background and it can be assumed that in the British school population of the early 1980s included a significant number of non-native speakers and/or bilinguals. A clear trend of improvement amongst non-native speakers is also apparent with considerable learning taking place from grade 11 to 12.

Grade 12 non-native speakers have not quite attained the level of competence recorded for their grade 10 native speaking counterparts. Figure 5 also shows a gap of about 15%, in terms of number of words mastered, between the native and non-native speakers in grade 12.

3. Weakest Words: An examination of the weakest words in each grade shows that while mean facility value increases from grade 10 to 12, the actual words represented remain largely the same (Table 5). For native speakers, seven of the ten weakest words in grade 10 are amongst the weakest in grade 12 also.

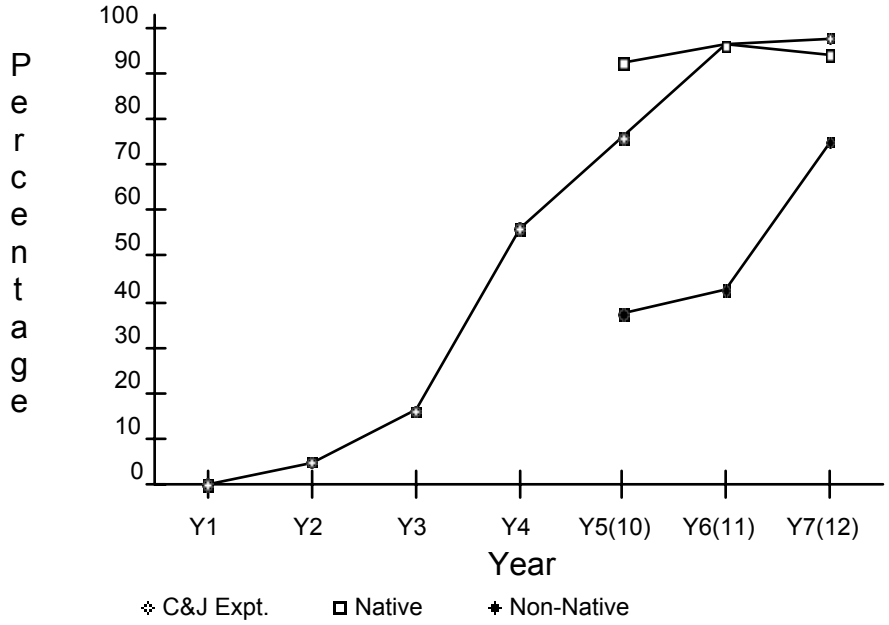

FIGURE 5: *Comparing mastery of the test words in the C&J study with native and non-native speaking portions of the present sample.*

TABLE 5: *Comparison of the ten weakest words in grades 10 and 12 for native speakers.*

	Grade 10	Grade 12
Common words	Converge Converse Incident Negligible Spontaneous Tabulated Valid	Converge Converse Incident Negligible Spontaneous Tabulated Valid
Unique words	Constituent Convention Relative	Coincide Evacuate Disintegrate
Mean Facility	52%	74%

While the overall variance between this sample and the C&J data is low at all three grade levels, large differences, both positive and negative, have been recorded for some of the words (Table 6). While certain words are weak in all three grades, the total number of words with a large variance as well as the magnitude of the variance grows as the student progresses through secondary school. This suggests that vocabulary enrichment is weak and that more attention needs to be paid to language development in science lessons.

For non-native speakers, five of the weakest words in grade 10 are also on the list for grade 12 and show almost no improvement in mean facility value (Table 7). The overall improvement for the ten weakest words is only 10% compared with 20 % for the test words as a whole.

For non-native speakers, certain words remain very weak showing variances of the order of -50% to -60% compared to the C&J data (Table 8).

TABLE 6: *For native speakers, words showing the largest negative variance compared to the C&J data.*

	Grade 10	Var. (%)	Grade 11	Var. (%)	Grade 12	Var. (%)
Common in all three grades	Converge Incident Relative	-14 -13 -10	Converge Incident Relative	-21 -29 -22	Converge Incident Relative	-23 -33 -15
Common in two grades	Constituent	-11	Constituent Coincide	-22 -23	 Coincide	 -16
Unique	Convention Efficient Sequence	-10 -10 -10	Accumulate Exclude Standard Symmetrical Valid	-22 -18 -28 -20 -25	Devise Disintegrate Evacuate Illustrate Immerse Negligible Tabulate	-22 -12 -25 -11 -11 -12 -29

TABLE 7: *Comparison of the ten weakest words in grades 10 and 12 for non-native speakers.*

	Grade 10	Grade 12
Common words	Constituent Exert Incident Immerse Valid	Constituent Exert Incident Immerse Valid
Mean facility	41%	42%
Unique words	Crude Diagnosed Disintegrate Impact Tabulated	Contract Converge Dominant Evacuate Phenomenon Reference
Mean Facility Value	42%	52%

4. Words needing special attention: Words defined as needing special attention were those with facility values less than 70% in at least three of the four formats tested. There is considerable carry-over from grade 10 to grade 12 in this regard with 19 words common to both grades (Table 9).

Words that cause problems for both native and non-native speakers tend to remain problematic throughout the final years of secondary schooling. Thus remedial action taken in grade 10 may help to alleviate the problem later on.

On the other hand, the list of words that cause problems is not the same for the two language groups, so that remedial action needs to be tailored to the specific needs of each language group. An approach directed at non-native speakers in a mixed class of native and non-native students, will not necessarily help the native speakers.

5. Word register: As a further piece of evidence to demonstrate progress over the final three years of secondary schooling and to compare this progress in native and non-native speakers, word register was measured, based on the test words in the C&J experiment, and is presented by grade and language category in Figure 6 below. This graph shows the average number of words from the ninety-word sample scored correctly at each grade level. For native speakers the average number of words in the register increases by 7, from 82 in grade ten to 89 in grade twelve. The increase of 8 words, from 63 to 71, for non-native speakers over the same time period is comparable.

While there is a trend of improvement in both language groups, the gap in terms of the size of the register for these words does not close significantly over the two-year period. It has already been shown that the proportion of non-native speakers who have "mastered" a certain word from the list increases by 10%. For native speakers the increase is 9%. Thus in grade 12, approximately nine out of ten native speakers could reasonably be expected to have mastered almost all of the words in the test list. For non-native speakers, slightly more than two thirds of the students can be expected to have mastered about three quarters of the list.

TABLE 8: *For non-native speakers, words showing the largest negative variance (%) compared to the C&J data.*

	Grade 10	Var.	Grade 11	Var.	Grade 12	Var.
Common in all three grades	Evacuate Exert Devise Constituent Converge	-30 -35 -32 -33 -30	Evacuate Exert Devise Constituent Converge	-30 -40 -53 -34 -51	Evacuate Exert Devise Constituent Converge	-38 -32 -32 -38 -35
Common in two grades	Crude Impact Modify Recoil Reference Standard	-43 -38 -32 -37 -30 -30	Crude Impact Modify Recoil Reference Standard Accumulate Contract Dominant Immerse Incident Phenomenon	-42 -40 -34 -34 -45 -32 -42 -45 -30 -61 -36 -40	 Accumulate Contract Dominant Immerse Incident Phenomenon	 -32 -35 -30 -40 -34 -38
Unique	Excess	-33	Abundant Audible Coincide Concept Convention Detect Disperse Limit Relative Retard Residue Stimulate Symmetrical Tabulated Valid	-36 -32 -46 -34 -32 -33 -31 -32 -35 -32 -41 -37 -34 -35 -44		

TABLE 9: *For non-native speakers, mean facility (%) for words needing special attention in both grade 10 and 12.*

Word	Gr. 10	Gr. 12	Word	Gr. 10	Gr. 12
Abundant	54	62	Incident	45	26
Constituent	39	45	Modify	53	65
Contract	51	51	Negligible	54	57
Diagnosed	47	68	Phenomenon	60	51
Disintegrate	41	67	Reference	49	51
Dominant	57	52	Relevant	61	57
Evacuate	54	51	Retard	50	60
Exclude	51	57	Sequence	58	58
Exert	44	49	Valid	31	47
Immerse	48	45			
			Mean	50 %	54 %

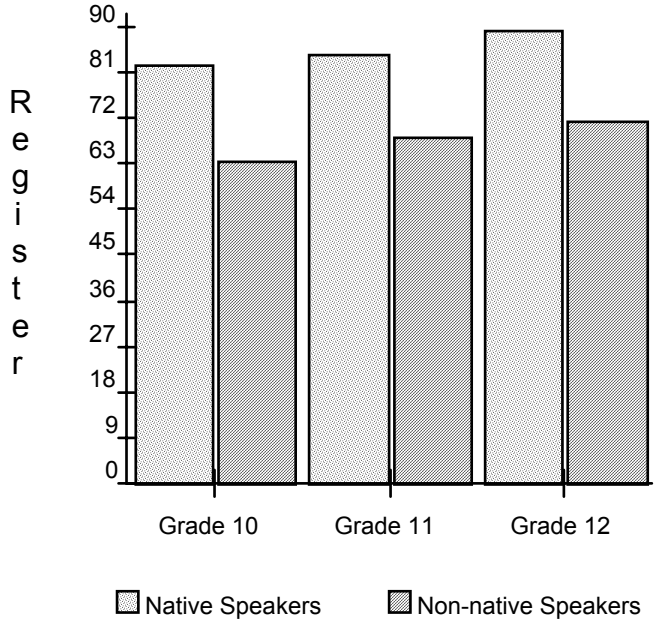

FIGURE 6: *Word Register by Grade.*

DISCUSSION

The results of this study clearly show that there are important deficiencies in scientific literacy, measured in terms of mastery of difficult non-technical vocabulary amongst pupils attending international schools. This is true of both native and non-native speakers of English, but to a much greater extent for the latter group. The evidence strongly suggests that higher priority needs to be given to language development in mainstream science classes.

The relative difficulty of format a appears even more strongly here than in the original 1980 study by Cassels and Johnstone (C&J). Amongst non-native speakers format b is also weak. It appears that there are many cases where the meaning of a word is understood in a scientific or everyday context, but where the meaning cannot be precisely stated out of context - resulting in weak format a and b scores. Thus context, even a less familiar one such as scientific context, may be helpful for setting in motion and directing the memory processes used to recognize meaning and correct usage.

Format c is consistently weaker than format d. In fact format d is the strongest format at all grade levels for both native and non-native speakers. This suggests that recognizing correct usage in an everyday context is slightly easier than in a scientific context. This is not surprising especially in the case of non-native speakers, who may only have had limited exposure to the variety of ways in which a word may be used. This is in keeping with the ideas of Cummins regarding the relative difficulty of acquiring interpersonal communication skills (BICS) on the one hand and cognitive academic language proficiency (CALP), on the other hand (Cummins, 1980).

The trend of improvement by grade follows more or less the same pattern as found in the C&J data. However, the increase in mean facility value from grade 10 to grade 12 is slightly smaller for the native speakers and is considerably smaller for non-native speakers. Thus at a time when secondary school students in a predominantly English speaking environment are learning to recognize and use a range of new vocabulary, students in corresponding grades in a multilingual setting are not demonstrating the same progress and are losing ground on their counterparts.

In terms of the number of words mastered, close agreement can be found between the C&J data and that obtained for the native speakers. In fact the native speakers in grade 10 in this sample fare considerably better than their Y5 counterparts in the C&J study. The non-native speakers also improve in this regard but with the pattern offset by almost two years. In other words grade 12 non-native speakers compare well with grade 10 (Y5) native speakers. The biggest gap is in grade 11 suggesting that not enough is being done to enhance vocabulary enrichment in grade 10.

In their study, Cassels and Johnstone hint at the magnitude of the gap between native and non-native speakers in terms of their mastery of non-technical vocabulary. They point to a large number of words that cause difficulties for non-native speaking third level students. Direct comparison with the results of the present study is not possible since the tests used were different. Nevertheless it can be seen that the difference in mean facility between native and non-native speakers of about 10%, which they recorded, compares well with this study. Moreover, many of the same words listed as being difficult for technical college students show up in this study also.

Strategies for recognizing meaning of unfamiliar words in multiple-choice questions may be influenced by a student's native language (Saville-Troike, 1984). Japanese students, for example, often look for words that have the same sequence of two or more letters in the same position, whereas speakers of European languages look for similar word stems. False cognates as well as words in the target language that have no equivalent in the learners´ L1 will vary from one language to another and may cause additional language-specific problems (Higgins, 1967). In terms of a number of factors, correspondence between the grades is stronger than between the language groups. This suggests that the long-term retention of new vocabulary and its particular context may be easier for the native speaker than for the non-native speaker. The fact that many of the words that are problematic for non-native speakers in grade 10 are still problematic in grade 12, suggests the need for specific programmes to improve vocabulary skills coupled with regular reinforcement. From the results of this study it seems clear that, from the perspective of the non-native speaker, such efforts need to be directed at grade 10 at the latest.

In a multilingual setting, the science teacher needs to create opportunities for language enrichment for both native and non-native speakers. Many such opportunities arise in the course of a normal science lesson and, without needing to be a language specialist, the science teacher may well be able to take advantage of these to the benefit of the students. The introduction of new vocabulary should ideally take place as a natural part of the lesson and not be "tacked on at the end". The context must be meaningful and not contrived. If these conditions are met, progress in vocabulary skills can be made without compromising the primary purpose of instruction, namely advancement in scientific knowledge and understanding. In fact, progress in understanding of scientific concepts will be enhanced.

Ideally the function of language development should be shared with the English or ESL teachers. Often they are just as reticent to tackle scientific language as the science teacher is to enter the realm of language teaching. The learning of language within science is an area which needs to be addressed in teacher training.

SUMMARY AND CONCLUSIONS

The conclusions reached here must be viewed in the light of the limitations of this study, including the difficulty of obtaining a large sample from an international population and the high level of diversity among the participating schools. Nevertheless it can be concluded that in addition to verifying the findings of Cassels and Johnstone in an international school setting outside of Britain, this study allows a number of important conclusions to be made.

1. There is evidence that language development in native speakers attending international schools is limited in many ways and that this can affect command of non-technical vocabulary in science.
2. There is a large gap in terms of mastery of non-technical vocabulary between native and non-native speakers at all grades. By grade 11 non-native speakers have lost considerable ground in this regard compared to their native speaking counterparts. In terms of vocabulary skills the magnitude of this gap can be put at about two years.
3. While the format in which a word is tested is generally not significant, this may be important for particular words - an effect seen strongly in non-native speakers.
4. Stating the precise meaning of a word out of context is more difficult especially for non-native speakers than identifying correct usage in either a scientific or everyday context.

RECOMMENDATIONS

In an international school setting, where the opportunities for language enrichment can be limited, higher priority needs to be given to language development in science classes. Science teachers need to be aware that certain everyday terms that have special meanings in science can cause considerable difficulty, especially for non-native speakers of English. With this in mind, vocabulary of this type needs to be introduced consciously and with support and explanation. Ideally this should happen as a natural part of the lesson and not as an "add-on". Science teachers should be sensitive about using this type of language on assessment items. Where the use of very difficult non-technical terms is unavoidable, teachers should make sure that meanings have been explained and exemplified.

In multi-lingual schools there is a need to develop specific intervention programmes to improve the use of language within science lessons, particularly, but not only for non-native English speakers. This puts an onus on science teachers to become familiar with certain language teaching techniques and to learn to apply and integrate them in the classroom.

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