THE INTERRELATIONSHIP OF PROFICIENCY IN A SECOND LANGUAGE AND UNDERSTANDING OF SCIENTIFIC CONCEPTS

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There is debate as to whether poor performance in academic tasks by English Second Language students is due to language difficulties or to conceptual difficulties. In this paper I suggest that these two aspects are very closely inter-related. Evidence from written tasks completed by students on a university bridging year suggests that students' proficiency in written English is dependent on their understanding of the task and the scientific concepts relevant to that task.

1. Introduction

In this paper I will raise some questions for which I do not yet have many answers. What do we mean by proficiency in English as a Second Language? Do we regard the measure of a student's language ability as fixed at a given time? In my work as lecturer in language development on the Science Foundation Programme at the University of Natal in Pietermaritzburg, a bridging year for science students at tertiary level, I have become interested in trying to understand better the interdependency of concept development and language. I will describe one example of what can happen to the written language of ESL students when there is incomplete development of a scientific concept. I will contextualise my attempt to understand the phenomenon in terms of current science education theory and linguistic theory of second language learning. Thereafter I will explore some of the implications that arise for diagnosing student learning problems as well as the ways in which we use student writing to assess language ability.

2. An holistic approach to producing able learners

In the Science Foundation Programme at the University of Natal in Pietermaritzburg, students from disadvantaged educational backgrounds who are planning to do a degree in science or the applied sciences are selected through a dynamic assessment to attend the year-long programme. They are required to have a good command of English as a second language. They must have a matric exemption and must have studied mathematics and one science subject at matric level.

The Science Foundation Programme aims to develop in these students the potential that they have shown during selection so that in the following academic year they may embark on a degree in science, or the applied sciences with strong resources within themselves to meet the demands of university study. For this reason the Science Foundation Programme's focus is

holistic. All aspects of the learner are addressed. Students are taught maths, physics, biology and chemistry with the aim of developing a firm foundation in basic concepts and scientific reasoning skills. They take part in a counselling course in which both personal counselling and vocational counselling is addressed. They take a course in English language development for which they get a credit towards their degree.

The work is intensive. The science subjects are entirely laboratory based in the first semester and students are required to do a great deal of talking and writing about the concepts they are studying. Laboratory sessions are typically three hours long which allows for work to be experiential and for students to deal with difficulties in understanding that they encounter as they go along. Students have to hand in a lot of work to be marked and checked for evidence of misconceptions and difficulties in reasoning. Work that is not satisfactory has to be resubmitted. As the year progresses students become better able to gauge the demands of an assigned task, and the number of assignments requiring re-submission diminishes.

Students are also made aware of the metacognitive aspects of learning. They are required to do a weekly reaction paper, an informal writing task in which they reflect on their own learning. The holistic nature of the Science Foundation Programme and the close cooperation of staff teaching in the programme makes it possible for transfers of learnings to be monitored, for teachers to make explicit reference to transfer, and for students to be aware of the value to learning of seeing that learnings made in one subject or learning situation can be applied in other subjects or situations.

All the students are black African students and are English second language (ESL) speakers. Language development is a central part of the Science Foundation Programme. They are enrolled on a credit course in language development, called *Learning, Language and Logic* which is available to any ESL student at the University of Natal in Pietermaritzburg. It is a learner-centred course which operates in tutorial groups. In the case of students from the Science Foundation Programme the course is modified. They are taught as a group of about 30 students on their own and the course addresses specific aspects of the other subjects that they are studying. In particular, they spend an extra 90 minute session per week working on the language aspects of an assignment that has been set by one of the other science subjects.

During the year, each science subject and the counselling component has five or six such "language and science" sessions. I meet with the instructor of a particular science subject and discuss how best to use the session. For example, during the first semester last year students in biology had to set up a simple experiment using a protist culture. In a series of three language

sessions over three months they did the following language exercises. In the first session they had to read two articles dealing with hypotheses and the concept of variables. They were required to answer questions that required a synthesis of the readings, and then formulate their own hypotheses for their experiments. In the second session they began the draft of the report on their experiment, using the session to explore fully what was required in a scientific report. By the third session, the biology staff had read and commented on the draft reports. In the language session students worked with their drafts and the biology staff comments to prepare their final report. These were then marked by the biology staff.

The value of these language sessions is that it is possible in them to focus on the process of producing a scientific report and the skills required by scientists to produce reports that are accessible to their readers, while the biology sessions focus on the process of observation and experimentation and the skills required by a scientist to carry them out. Obviously both types of skills are essential to the scientist. While competent scientists have to use these skills in an integrated way, it is very difficult to teach content and process in an integrated way. We see the above as a way to meet both needs.

3. Writing for language development and for learning

In both language development sessions and science sessions students must work interactively, experientially and they must learn how to articulate the concepts that they are exploring (Perkins, 1989). As mentioned above, students' science work is entirely laboratory based in the first semester. Students are encouraged to work together, to help one another, to share ideas. Students are required to talk science and to talk their way through problems, both with their peers in pairs or groups of four, and with tutors. In this way the learner clarifies the concepts studied and monitors his or her understanding.

Language is the means by which the learner captures and works with those concepts that he or she does not yet fully understand. As English is the medium of instruction at the university, and the language in which students will study their courses for the science degree, English is the language in which they have to operate in formal discussions or written assignments. As students write assignments of different kinds they learn the conventions of academic writing. As they grapple with how to express concepts clearly so that they can be understood by their reader, they strengthen their own understanding of that concept. William Stafford is quoted by Paul Connolly in *Writing and the ecology of learning* as saying "a writer is not so much someone who has something to say as he is someone who has found a process that will

bring about new things he would not have thought of if he had not started to say them." (Connolly, 1989:2)

In expressing ideas in writing ESL writers have the advantage of being able to control the rate of output. Writers can slow down the process to a rate that is comfortable for them. They can give themselves space to think before committing themselves on paper, and once written down, the ideas and explanations can be referred back to, and refined or edited or elaborated.

Writers have the concrete evidence of their own writing that they are involved in the process of constructing knowledge. As they do more and more writing they develop different attitudes towards making mistakes. The process of writing down one's ideas, and having a reader respond to them develops new attitudes towards learning, to regarding it as a process of refining, correcting, and collaborating with other learners until understanding is achieved.

Written assignments in the Science Foundation Programme have two purposes: they are to give students practice in writing in English and using written English appropriately for academic purposes, and they are to provide a vehicle for students to develop a deeper understanding of the subjects they are studying.

To achieve the first purpose, that of giving students opportunities to improve their English, the language development course makes heavy demands on the students. They spend six hours per week in language sessions during which they are required to speak English. They hand in at least two writing tasks per week in the language course, and in addition, the lecturer assesses the assignments handed in to the other subjects that have been worked on during the "language and science" sessions.

To achieve the second purpose, that of using writing as a means for developing deeper understanding of the concepts they are studying, students are required to do a number of writing assignments in each subject. For example, in Chemistry they wrote a newspaper report on the feasibility of opening a potash mine and an essay on the extraction of metals, and had to give written explanations of the differences between terms like "mole" and "molecule" etc. In Mathematics they had to give written explanations of what they understood by mathematical symbols and equations and how they had solved certain problems.

4. Assessment of students' writing

As the language teacher I mark students' writing for both aspects, namely using English appropriately and demonstrating understanding of scientific concepts:

> "When teachers read writing assigned for reinforcement (of the second language) they correct errors; when they read writing assigned for communication and fluency, they react and respond to the content. When writing for learning is the dominant purpose however, teachers find that they combine these two: ... their role is analogous to that of a coach, who works on the whole performance as well as on the separate activities that constitute the performance, examining and evaluating all the while." (Raimes, 1987:41)

In attempting to assess each student's writing, I use the term "proficiency level" to indicate an assessment that I have given a particular task. I have identified three proficiency levels for assessment of written tasks. (Bachman, 1990:16; Lennon, 1990; and others) Each level of proficiency is characterised by a group of criteria. These are based on how effectively the writing communicates that the student has understood the demands of the task. Some of these criteria at each level are as follows: level one, the lowest level indicates poor language ability, many surface errors, poor organisation of ideas, misunderstood topic, and is generally difficult to follow. Level two indicates adequate language ability, few surface errors, adequate organisation, adequate grasp of the topic, and adequate ESL writing. The third level indicates very few surface errors, good organisation, strong topic control, and fluent writing.

While these grades need to be refined if they are to be used in a more diagnostic way, I am able to gauge the development of language ability of any student in the group, by making a profile of each student using the assessed level of language proficiency demonstrated in each writing task over the two semesters that they are in the Science Foundation Programme. During last year I read through some 60 items of writing from each student and assigned to each item one of the three levels of language proficiency mentioned above. As I had expected, all the students showed an overall trend of increasing language ability, although there were fluctuations between individual items.

5. A case of language deterioration

To recap, students use writing not merely to state what they already know but to develop the concepts that they need to master. The close inter-relationship of language and scientific understanding is recognised, although not fully understood. We try to develop students' language ability in order to provide a stronger tool for developing conceptual understanding. But it is looking at the relationship of understanding and language from another angle that has raised some important questions for me.

One exercise that students were required to complete in mid-October last year, three weeks before the final exams, gave some very unexpected results. At this stage in their biology curriculum the students were doing a project on designing their own ideal weed. They had been introduced to all the botanical terms they required for their work on flowers via a short article. This work had led them into discussion of many aspects of plant growth. In biology they had seen part of a film which described the changes in flowers as a result of insects acting as agents of pollination. It was a David Attenborough film which took as given the evolution of form, colour and smell in flowers through natural selection. In a language/biology tutorial students were asked to write an explanation of the changes that had occurred in flowers as a result of insects acting as agents of pollination.

In the language session, students were encouraged to work together, draw on their observations from the film and any other source, and complete the task - a one page assignment - during the 90 minute session. As usual the tutor and demonstrators were available to discuss aspects of the assignment. Although the tutors' work in these sessions is to focus on problems students encounter with the language demands of the task, for this particular assignment all the tutors were able to deal with the biological content as well.

The assignment was marked by the biology lecturer and the language lecturer. Our initial impression was that the majority of students had produced very poor work. What had seemed to us to be a relatively straightforward task was almost unmarkable from the biology lecturer's point of view. While I could tell that the assignment had been incompetently done, my astonishment was at the poor language the students had used and the lack of coherence in their writing. On further reflection it occurred to me that although the set task was very straightforward, if students did not have a working knowledge of the theory of natural selection, variation and evolution, they would not understand the dynamics at work. Thus an apparently simple task that asks for a description of a phenomenon may become an impossible task if the student does not have an adequate understanding of the concept that underlies the phenomenon.

The evidence of deterioration of the students' language is very serious. As I have said above, language is the vehicle with which the student deepens conceptual understanding. Obviously, if the student's language ability is poor, the student will not have a robust means of deepening his or her conceptual understanding. But the above case gives evidence of the other side of the coin. If the student's conceptual understanding is weak, the usually fluent ESL student loses his or her fluency in written English when trying to struggle with the task.

Let me demonstrate what I have termed "language deterioration" in two usually fluent ESL students. Below I have reproduced a short extract from the first student's biology assignment, headed "Biology text: Student A" and together with that extract, two short extracts from writing tasks that the student completed at about the same time. The extract headed "Chemistry text: Student A" is from a written assignment on the extraction of metals. Students had had some time to research the subject. In a chemistry/ language session students worked on the assignment, which they handed in the following day. The one headed "Language text: Student A" is extracted from a task written after a language session which dealt with some student grammatical errors: students had to submit a paragraph which began : "A good student is someone who ..."

Biology text: Student A	Chemistry text: Student A	Language text: Student A
Flowers have changed greatly as a result of pollinators. Plants mostly favours cross-pollination which results in variations and healthy offsprings. Insects have been one of the agents of pollination. Flowers have changed in order to promote insect pollination mechanism since Insects appeared to be efficient. Flowers are immobile and are therefore depend on Insects and other mechanisms for cross pollination....	Metals occur in nature as pure elements like gold and silver and others occur in compounds. The ones that occur as pure elements have a very low reactive ability. But other metals have a very high reactive ability and therefore they combine with other elements to form compounds. These metal compounds which are also mixed with other impurities are called metal ores....	A good student is the one who is motivated to work. He works consistently and put much effort in whatever he does. He does not leave his work until the last day of submission. He is an active reader. He reads with understanding and comprehension and work towards constructing his own knowledge from what he has read. He is an adventure. He is always ready to take up challenges.

Looking at the "Biology text: Student A," it is possible to identify a number of surface errors. There is a lack of agreement of subject and verb "Plants favours". There are two examples of incorrect use of plural nouns: "variations and healthy offsprings", "insect pollination mechanism". Thirdly, there are a number of examples of inconsistent use of tenses: "Flowers have changed...", "Plants...favour...". "Insects have been.. " "Flowers have been...". "Insects appeared to be efficient...", "Flowers are immobile...".

There are also errors of coherence at a deeper level. The writer makes no attempt to explain the terms used or to clarify the introduction of the term "cross-pollination" in addition to "pollinators" and "pollination". There is no elaboration on what is meant by the efficiency of the insects, "...insects appeared to be efficient." The writer jumps from a general statement about pollinators, then focuses on insects specifically, but then in the last sentence of the extract has generalised once more, "insects and other mechanisms". There are also suggestions that plants have made certain conscious decisions: "Plants favour...," "Flowers have changed

in order to promote insect pollination". The net effect is that the paragraph does not develop smoothly or logically.

Looking at the two other extracts from writing by the same student at about the same time, I believe that it is possible to conclude that the biology extract is unusually incoherent for this writer. Although there are some surface errors in "Language text :Student A" (an incorrect use of the definite article in the first sentence, two errors in subject -verb agreement: "He ... put much effort", and "he...work towards.." and a spelling error "adventure" in place of "adventurer") there is clear evidence of the development of ideas. Similarly in "Chemistry text:Student A" there is a logical progression from the general statement to an elaboration of that statement in the subsequent sentences.

The extracts from the second student's work on the same three assignments shows a similar difference in fluency between the biology text on the one hand and the chemistry and language texts on the other.

Biology text: Student B	Chemistry text: Student B	Language text: Student B
...In Yucca flower insect lays eggs and cover them with juicy sticky substance. When the eggs hatch, the small insects feed on that substance. On leaving they take along pollen to fertilize other flowers. Some plants have different markings visible under ultraviolet light which can only be seen by insects directing them to the pollen.	A number of types of ores of metals occur in nature e.g. oxides, carbonates, sulphides, halides, sulphates, silicate, phosphates and native ores. Metallurgy is the science of extracting metals from their ores and preparing them for use. Its history can be taken back to 8000 BC where the first native metals gold, silver and copper were discovered in stream beds and river banks....	A good student is someone who is thirsty for knowledge. He is ambitious and has a goal in life, and does everything in his power to reach it. He is not passive but active in his actions especially in thinking. He knows that knowledge is not something that can be poured to fill in an empty vessel, but changes dynamically. Therefore it is subjected to questioning and scrutiny....

Looking at the surface errors in "Biology text:Student B", which is taken from the end of the assignment, again there is a lack of subject - verb agreement: "...insect lays eggs and cover them...". There are many examples of the absence of the article: "In Yucca flower insect lays eggs and cover them with juicy sticky substance." In the fourth sentence, a lack of punctuation makes the sentence difficult to follow.

There are a number of errors at the level of organisation of ideas and coherence. Firstly, "In Yucca flower..." could mean "In the case of the Yucca flower..." or it could mean "An insect lays eggs *in* the Yucca flower." In the third sentence it is not clear how the pollen becomes associated with the small insects. In the fourth sentences it is not clear how the word "Some"

relates back to the previous sentence. In fact, the sentence actually introduces a completely new example, and there is actually no link between the two examples. The meaning of the fourth sentence is unclear on two counts, namely to what does the word "different" refer? Secondly the meaning of "...can only be seen by insects directing them to the pollen" needs clarification. Finally, the student concludes with a one sentence paragraph that reads, "Therefore with all these changes and influences flowers and insects are interdependent." Firstly, it is difficult to see how "Therefore" links with the ideas expressed in the previous paragraph. Secondly, neither of the examples in the extract above are explained as "changes" or "influences" and so the link here is unclear.

Comparing "Biology Text: Student B" with the other two extracts from that student's writing, I again conclude that it is considerably less fluent. In "Chemistry text: Student B" although there is some clumsy expression "A number of types of ores of metals..", the ideas flow logically, and the links between the ideas are well made. "A number of types of ores of metals occur in nature... Metallurgy is the science of extracting metals from their ores...Its history ..." . Similarly, in the "Language text: Student B", the idea "thirsty for knowledge" expressed in the first sentence is clearly elaborated in subsequent sentences. Incorrect use of "Therefore" in the last sentence, and inappropriate use of "fill in" rather than "fill" in the fourth sentence are the only errors.

To summarise, students who are regarded as fluent ESL speakers may exhibit a high level of proficiency on one task and a much lower level of proficiency on another written task given within a short space of time. My hypothesis is that the apparent deterioration in language is a result of a lack of understanding of the underlying concepts involved in the task.

6. Discussion of results

I have focused on the work of two of the students in the group to demonstrate the deterioration in their written language in the biology assignment. However, in this particular exercise this deterioration was common across the whole group. Those students whose work I have discussed are among the most able in the group, and the difference between the biology text and the other two texts is highly illustrative of the phenomenon that I am describing. I think it is important to note that I was only in a position to notice this unexpected deterioration because I had a very comprehensive profile of each student's language development over two semesters, and because this happened at the end of the second semester, and not at the beginning of the year when I did not yet know the language ability of each student.

Is the case that I have described above an isolated incident, and a very severe, but unusual example of language deterioration, or could it be more widespread, and a feature of learning that we have to consider seriously? I think the particular set of circumstances of the biology exercise may have given rise to some of the results. Certainly, I would imagine that if a student had a very poor grasp of the theory of natural selection and how variation comes about in living organisms, confusion about the various time scales and the mechanisms involved would lead to a loss of control of the use of tenses in a description of the process. In addition the writer may give the impression that conscious decisions to change are made by plants and insects. This may be an explanation for some of the particular errors in "Biology Text:Student A". Similarly, the particular convention in scientific language where one uses articles to denote general or specific ideas may be very confusing for the ESL student. If we return to "Biology text:Student B" a corrected version of the first sentence could read: "In *the* Yucca flower *an* insect lays eggs and covers them with *a* juicy, sticky substance." Or it could read "In Yucca flowers, insects lay eggs and cover them with a juicy, sticky substance."

I believe that the consequences of this inter-relationship between ESL proficiency and understanding of scientific concepts are very important. There is a need to research this relationship. My initial research leads me to believe that input from a number of areas of linguistics, as well as cognitive science, are demanded. Let me explore some of these consequences further.

Firstly, it raises questions about proficiency in ESL and what we actually mean by assessing a student as an advanced ESL speaker or writer. If I set a task for ESL students and they give evidence of poor language skills and lack of coherence they will get a low score on the task. There are two possible conclusions I can reach from a poor performance. The first is that the student has poor language ability in English. The second is that the student does not understand the concept about which he is writing and, in addition, may or may not have poor language ability in English. The implication of reaching the first conclusion is that I may categorise the student as having limited ability in English. This might lead to my rejecting a student from going on to a further course because of poor English. The implications of the second conclusion are that the student does not understand the concept that I have been testing, or the student does not understand some deeper underlying concept, and, in addition, may or may not have limited ability in English.

Thus, apparent lack of proficiency in English on a particular task may be indicative of one or more of the following:

(a) poor ability in English that prevents adequate achievement of the task;

(b) poor understanding of the demands of the task;
(c) misconceptions about the concepts that the task is designed to test;
(d) misunderstanding or lack of knowledge of underlying concepts that the task concepts are based upon.

What, then, do we understand by assessing an ESL student as an "advanced speaker of English as a second language"? Do we mean it as a general and fixed characteristic of that person? Do we qualify our assessment to the effect that, given an academic task that this student understands, he or she is an advanced speaker of English as a second language?

In many tertiary institutions where English is the medium of instruction, ESL students are admitted on the basis, among other things, of their language ability in English. How can selectors be sure that students that they accept may not demonstrate poor levels of proficiency in English on subsequent tasks in their studies? More important, perhaps, is the question: how can selectors be sure that the students they turn away because of poor levels of English proficiency may not have performed badly because the conceptual demands of the task in the language test were beyond their present understanding? At the present time, selection procedures being developed by many tertiary institutions are attempting to predict students' potential to succeed in the work demanded by the degrees or diplomas offered by these institutions. How can we, as selectors, claim to be assessing the student's potential to succeed if we assign an ESL proficiency level to that student on the basis of performance on a task which may be demonstrating conceptual misunderstanding, and related language deterioration?

The second area of importance is the teaching and learning of English as a second language. Research in linguistics needs to inform teaching methodology with regard to the relationship between conceptual development and language. Research on thinking, on conceptual change, on styles of thinking, on the relative importance given to particular styles of thinking in mother tongue acquisition should be extended to sociolinguistic research, and the growing understanding of the importance of pragmatic competence in learning a second language.

Communicative language teaching has always advocated that the ESL student should not learn English in isolation from authentic communication situations. I believe that the inter-relationship between concept development and language ability makes a strong case for a much closer interaction between English second language learning and the language demands made upon students in the other subjects that make up the rest of their study programme. This necessitates collaboration between the language teacher and the subject specific teacher or

lecturer, something that does not happen very easily or frequently in undergraduate courses at the university where I teach.

Next, ESL teachers have to ensure that students are fluent enough in English to sustain the concept formation and understanding demanded by the academic subjects they are studying. As I have mentioned above, this has implications for how we assess students' language ability if they are to be studying in a second language. We need to be better informed about what would constitute a satisfactory command of ESL to allow the student to manage to learn in English and how one goes about establishing the presence of that language ability.

The area that I will address finally is that of the important implications of this close relationship of proficiency in English and the understanding of scientific concepts for the teachers and lecturers of other disciplines at the university. If lecturers are concerned about how well their students are developing the concepts required by that subject, or to put it another way, if lecturers are concerned that their teaching should enable students to formulate the concepts required by their discipline, they need to be alert to the possible reasons why a student or students may have answered an assignment unsatisfactorily.

How can lecturers diagnose conceptual difficulties that ESL students may be experiencing when these difficulties are so well disguised by poor language in the unsatisfactory assignment? If the lecturer attributes such writing to the fact that the student must have language difficulties, he or she misses the fact that poor understanding may be the cause of both the poor language and the unsatisfactory answer. ESL and subject lecturers must work together to identify which difficulties are conceptual in nature and which arise from a lack of language proficiency. Perhaps deterioration in the language of an otherwise articulate ESL student could serve as a warning signal to the subject specialist that there are conceptual difficulties present.

In dealing with the new group of students who began in the Science Foundation Programme in February this year, I am very consciously looking at the relationship between ESL proficiency and understanding of the scientific concepts with which students are working. To date the other teachers have commented on the students' lack of precision, inability to answer the question assigned, and illogical reasoning. In the main the language teachers have assessed written tasks in the lower rather than upper levels of proficiency. We think beginners' lack of fluency may be related more to poor understanding of science concepts than to the general process of initial orientation to the demands and conventions of the Science Foundation Programme. This is the area of ongoing research for teachers in the Science Foundation Programme.

In conclusion, I would like to underline the point that language development for academic purposes of ESL students at tertiary institutions is closely associated with their grasp and understanding of the discipline-specific concepts that they are studying. Developing resourceful autonomous learners who do well in their chosen courses of study is part of the language teacher's responsibility.

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