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The Influence of Second Language Teaching on Undergraduate Mathematics Performance

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Understanding abstract concepts and ideas in mathematics, if instruction takes place in the first language of the student, is difficult. Yet worldwide students often have to master mathematics via a second or third language. The majority of students in South Africa – a country with eleven official languages – has to face this difficulty. In a quantitative study of first year calculus students, we investigated two groups of students. For one group tuition took place in their home language; for the second group, tuition was in English, a second or even a third language. Performance data on their secondary mathematics and first year tertiary calculus were analysed. The study showed that there was no significant difference between the adjusted means of the entire group of first language learners and the entire group of second language learners. Neither was there any statistically significant difference between the performances of the two groups of second language learners (based on the adjusted means). Yet, there did seem to be a significant difference between the achievement of Afrikaans students attending Afrikaans lectures and Afrikaans students attending English lectures.

Introduction

Mastering undergraduate mathematics is sometimes considered to be a two-step process. First, students have to understand the mathematical concepts (Richards, 1982; Thurston, 1995) and second, they have to be able to communicate their understanding of these concepts in written format (Brown, 1994).

In the first step, the lecturer clarifies concepts by using two verbal languages: a commonly spoken, everyday language and a subject-specific, scientific language. Therefore the student has to be proficient in both these languages. Moreover, competency in the former does not imply competency in the latter (Lemke, 1990).

In the second step, students have to familiarise themselves with the scientific manner of communicating acquired concepts in writing. This step is especially important if one considers that students need to be able to read and write mathematics when using textbooks, and be able to complete various assessment activities in writing during the course.

This two-step process is a simplified approach to learning mathematics and does not take into account the influence of various other factors (e.g., emotional support, learning opportunities, personality traits of the student). Still, we used as a point of departure in this study the premise that successful completion of a mathematics course relies heavily on two aspects of language:

- effective communication between the lecturer and student; and
- the student's ability to understand and communicate abstract concepts when *translated* into written mathematics.

In this article the findings of a quantitative study on the influence of second language learning on students in South Africa, with the emphasis on the second of these two aspects of language, are reported.

South African Background

Political changes during the past decade in South Africa placed the language issue at universities under the spotlight. The language of the former South African apartheid government was predominantly Afrikaans – a language of Dutch origin, spoken mostly by white Afrikaners and the Cape Coloured communities. With the advent of democracy in 1994, it was decided to recognise 11 official languages. English is becoming the lingua franca by default – not by official policy.

Fewer than 10% of South Africans are English first language speakers, and the rest of the population is notably heterogeneous. This diversity within the group of second language learners complicates the matter of learning via a second language even more. An indication of the proportional distribution of home languages in the South African population (Statistics South Africa, 2003) is given in Table 1.

Table 1
South Africa: Distribution of home languages (2001)

Home language	% of population	Home language	% of population
IsiZulu	23.8	Sesotho	7.9
IsiXhosa	17.6	Xitsonga	4.4
Afrikaans	13.3	SiSwati	2.7
Sepedi	9.4	Tshivenda	2.3
Setswana	8.2	IsiNdebele	1.6
English	8.2	Other	0.6

South African universities and their governing bodies decide on policies concerning the language(s) in which lectures are presented. The outcomes of this study and of similar studies should contribute to the making of informed decisions on this issue. Many of the traditional Afrikaans medium universities (i.e., where Afrikaans is the language of instruction, such as the

University of Pretoria) find the need to at least partially convert to English as a teaching medium because they now cater for a wider section of the South African population.

In an article on the performance of grade 12 students in 2002 (Mboweni-Marais, 2003), it was suggested that students who receive secondary level tuition in a language other than their mother tongue, are at a disadvantage. In reaction to this and similar reports, many prospective students and parents from the Afrikaans speaking community were dissatisfied with the shift in teaching medium from Afrikaans to English. They believed that having to change from Afrikaans-medium primary and secondary education to English-medium tertiary education may negatively impact on the students' academic performance. This has been one of the factors motivating some universities to present – as far as practically possible – parallel lectures in English and Afrikaans, casting an additional financial and logistic burden upon the university. Although code switching – the teaching method by which the speaker switches between the first and the second language in a single session (Adler, 1998; Rollnick, 2000) – could offer a possible solution to the problem of parallel sessions, it slows down lectures and also assumes exceptional bilingualism of the teacher.

The concern about the language issue and the implications of the current double-sessions led us to focus our attention on Afrikaans first language students in this, our initial study on the influence of second language tertiary mathematics teaching in South Africa – a country with a variety of cultures and languages.

The language situation in South Africa needs to be considered in more detail. There is no doubt that the importance of English as the common language countrywide (and internationally) is recognised by all. It is a priority of parents and teachers alike to promote a command of English amongst students, and it is generally accepted that a command of English is imperative for success in the professional sector.

English is indeed the language of instruction for secondary schooling for all cultural groups, except for the Afrikaners. However, most Afrikaners, especially in urban areas, have an excellent conversational command of English due to social exposure, television, and to taking English as a compulsory subject for at least 10 of their 12 years of schooling. It can then be generally accepted that all students entering the University of Pretoria have a fair level of academic proficiency in English.

Although it is generally accepted that the University of Pretoria offers instruction in both Afrikaans and English, campus wide there is an underlying sensitivity regarding the language policy. This sensitivity can be traced back to the fact that Afrikaans used to be the sole language of tuition at this university and so the new dispensation arouses a feeling of protection towards a "threatened" language and culture. This is prevalent only amongst a sector of the student population. These students feel that they still have the option of home language tuition and they want to keep it that way.

Students come from culturally diverse backgrounds and this can cause some groups to be at a disadvantage when dealing with "real-life" problems such as making use of a pack of cards in probability problems. Here the Afrikaners are probably at less of an advantage because the Afrikaner and English cultures both have a European founding and differ significantly from the African culture. With more and more African students attending urban, culturally mixed schooling and with an African middle class rapidly expanding so that access to television becomes more common, these cultural differences are diminishing.

Literature Review

Much research has been conducted on the effect of second language teaching in elementary and secondary mathematics education (Adler, 1998; Cocking & Chipman, 1988; De Avila, 1988; Leap, 1988). However, little research has been undertaken in the field of second language teaching of university mathematics. Barton and Neville-Barton's (2003) article on language issues of university students is one of the few studies published and will be discussed in more detail subsequently. The literature cited in this review mostly refers to education at the lower levels.

A variety of factors influences students' academic (and specifically mathematics) performance and it is necessary to take careful consideration of these factors before embarking on a study dealing specifically with the issue of language. According to Cocking and Chipman (1988) the three major categories of influence on school learning are:

- entry characteristics of the learner;
- educational opportunities provided to the learner; and
- motivation to learn.

Some of the specific factors cited in the literature as influencing academic performance include:

- home socio-economic status (Cocking & Chipman, 1988);
- teacher competencies (Cocking & Chipman, 1988);
- parental encouragement and assistance (Cocking & Chipman, 1988; Tsang, 1988);
- sex role stereotyping (MacCorquodale, 1988);
- culture (Saxe, 1988); and
- background in mathematics (Barton & Neville-Barton, 2003).

These factors do not necessarily belong to only one of the three categories mentioned by Cocking and Chipman (1988). For instance, a student's culture might create a linguistic disadvantage at entry level whilst social customs within a culture may also influence a student's motivation to perform well in mathematics.

Language also does not necessarily fall into a single category. The influence that language has on mathematics learning refers to more than just the influence of the student's home language. It also refers to factors like the effectiveness of communication between the lecturer and student, between the student and written text, and to the linguistic skills of the lecturer. In the end language may be categorised, for instance, as an entry characteristic and as an educational opportunity. Barton and Neville-Barton (2003) also point out the complexity of the language issue. This complexity makes it very difficult to view the role of language in mathematics learning in isolation. Complicating the matter even more is the fact that the conclusions of different studies sometimes contradict each other (Cocking & Chipman, 1988), as is the case with De Avila (1980) and Mestre (1981). In a study of grades 1, 3 and 5 Hispanic students, De Avila found that language proficiency was not strongly predictive of mathematics achievement, but Mestre reported a significant positive correlation between problem solving and language proficiency of Hispanic college students.

Focussing attention on understanding the role of language in mathematics learning, in this study we analysed the process of studying mathematics. This approach is linked to the preceding discussion in that it is still influenced by the factors mentioned in the first approach. However, it is more localised in that it focuses on a shorter time period, puts special focus on the students' mathematical communication skills and is much simpler than the previous approach.

In order to achieve the necessary in-depth mathematical understanding (or *basic mental infrastructure* as Thurston, 1995, calls it), Thurston (1995) suggested that effective communication of mathematical ideas was the key. Language forms an integral part of this communication. McLean (2000) supported this and said that many of the learning problems of students originate from an inadequate knowledge of the basic vocabulary. Bohlmann (2001) also discussed the role of language: "It [language] is the medium by which teachers introduce and convey concepts and procedures, through which texts are read and problems are solved" (p. 6).

In a citation of recent studies on second language learning in science, Rollnick (2000) stated that "… it is acknowledged that expecting students to learn a new and difficult subject through the medium of a second language is unreasonable, giving them a double task of mastering both science content and language" (p. 100). This double task entails the acquisition of two conceptually difficult and different skills at once – one being related to language, and the other to mathematics content (Bohlmann, 2001).

What level of second language proficiency is necessary to cope with a second language as instruction medium? According to Heugh (1999) the minimum vocabulary necessary to cope with English as the instruction medium is 5000 words. She claimed that after four years of home language medium instruction in primary school, accompanied by English as a subject, a student would have acquired only about 800 words.

In the case of English second language students in the South African schooling system, students are formally exposed to English from the first grade and they complete the English second language curriculum up to grade 12. Should they be proficient in both Afrikaans and English, their bilingualism could be an advantage in their studies, enabling them to see different representations of a single idea (Bohlmann, 2001; Rollnick, 2000).

Proficiency in conversational English is not the only prerequisite for English second language students to master mathematics. They also need to be familiar with scientific English. According to Lemke (1990), "… the mastery of a specialized subject like science is in large part mastery of its specialized ways of using language" (p. 21). The difference between conversational and scientific language is considerable, since, according to Rollnick (2000), "…the difference between everyday language and science or mathematics terminology also leads to first language speakers learning a new language when learning science" (p.100).

Mathematical English entails the use of abstract generalisations and logical relationships (Lemke, 1990) that both first and second language students have to master. Barton and Neville-Barton (2003) regarded proficiency in mathematical English to be a more important factor than proficiency in general English in the learning of university mathematics.

In our introduction it was surmised that successful completion of a mathematics course relies heavily on two aspects of language, of which the second refers to students' ability to communicate mathematics in a written format. The written mathematics includes the genres of proof, definitions and theorems (Lemke, 1990; Marais, 2000). Students need to learn to formalise mathematical concepts, using mathematical text and symbols. Cocking and Chipman (1988) referred to Spencer and Russell (1960) who claimed that the difficulties in reading mathematics were due to the specialised language used, for example, for expressing ratios, fractions, and decimals. According to Brown (1994): "For someone learning mathematics there is a similarity with learning a language in that there is a need to grapple with an inherited mode of symbolization and classification, arbitrarily associated with some pre-existing world" (p. 142).

Cocking and Chipman (1988) also referred to studies by Rosnick and Clement (1980), Clement, Lochhead and Monk (1981), Kaput and Clement (1979), and Rosnick (1981) all of whom reported on the widespread inability of university engineering students to translate relationships expressed in natural language into corresponding mathematical expressions and vice versa. This inability can be seen as a lack of mathematical literacy. The importance of high levels of mathematical literacy becomes even more evident when one considers that fluent reading and understanding of mathematical text and symbolism are essential for studying textbooks (O'Toole, 1996).

In their study of 83 volunteer first year students, Barton and Neville-Barton (2003) found that because of a lack of understanding of mathematical text, students (mainly Asian) who have English as an additional language (EAL students), were at a 10% disadvantage in comparison with English first language students. They also found that although written mathematics can take the form of text, symbols, diagrams or graphs, second language students preferred mathematical symbols to texts, diagrams or graphs to express themselves, especially in the case of text questions.

The issue of bilingualism and its relation to linguistic and cognitive development has been addressed by a number of researchers. A theoretical framework for research into the developmental interrelations between language and thought has been put forward by Cummins (1991, 1998). This theory is based on two hypotheses. The first is the *threshold hypothesis*, suggesting that learners who have attained high competency in their second language, at no expense to their competence in their first language, have a potential cognitive advantage over learners with competence in only one language (Lambert, 1977). The second hypothesis is the *developmental interdependence hypothesis* which predicts that the abstraction level of the mother tongue is important for mastering conceptual operations connected with mathematics (Cummins, 1979).

Cummins (1978) distinguished between *linguistic* bilingualism (pronunciation, grammar, fluency, etc) and *cognitive* bilingualism (the ability to make effective use of the cognitive functions of the language). Dawe (1983) discussed the idea of a *linguistic distance* between languages, an indication of the lack of resemblance between different languages, or how "far apart" languages are. It is possible that the greater this distance between learners' first languages and English, the greater the learning task in mathematics. In South Africa, the linguistic distance between Afrikaans and English is probably much smaller than the distance between English and the African languages used in the country.

There is general consensus among researchers about the importance of logical connectives in English (for example "so that" "but", "if … then", "suppose", etc.) in reading comprehension learning and thinking (Dawe, 1983; Gardner, 1977). Although these connectives are part of spoken English, they have definite use in mathematical English and are used in a more formal sense.

Many empirical studies have reported a positive association between bilingualism and students' linguistic, cognitive, or academic growth. For a comprehensive review of the interplay between language and mathematics learning, the reader is referred to Ellerton and Clarkson (1996). In early research, Malherbe (1946) conducted a large-scale study of Afrikaans-English bilingual education in South Africa involving 19,000 students. Malherbe (1946) found that students instructed bilingually did at least as well in each of the languages as students instructed monolingually. Malherbe (1946) argued for the benefits of bilingual education and the data were consistent with Cummins' (1979) interdependence hypothesis.

Research findings are consistent with respect to three issues: (i) the distinction between conversational and academic skills in a language, (ii) the positive effects of bilingualism on learners' awareness of language and cognitive functioning, and (iii) the close relationship between bilingual students' academic development in their first and second languages in situations where students are encouraged to develop both languages. Some teachers and parents tend to encourage students to give up their first language and switch to English as their primary language of communication; however, the research evidence suggests that this retards rather than expedites academic progress in English (Cummins, 1991).

Dawe (1983), based on findings from a study with secondary school learners in England, agreed that first language competence is an important factor in the learner's ability to reason in mathematics in English as a second language. This phenomenon gives considerable support to theories that assert that a cognitively and academically beneficial form of bilingualism is dependent on adequately developed first language skills. However for both English monolingual and bilingual learners knowledge of logical connectives in English is a crucial factor.

In a study involving primary school learners in Papua New Guinea, Clarkson (1992) and Clarkson and Galbraith (1992) found that bilingual students competent in both languages outperformed monolingual students, and that bilingual students with low competence in both languages were disadvantaged compared with other groups of students. Clarkson and Dawe (1997) found that bilingual students interchanged languages when doing mathematics and that this exchange was influenced by the mathematical context, schooling and learners' competencies in their languages.

Objectives

In this study we have begun to explore the influence of second language mathematics teaching on the diverse population of second language tertiary students in South Africa. We investigated the hypothesis that the Afrikaans first language students had sufficient understanding of English to complete a tertiary mathematics course successfully.

The primary objective was to investigate the differences in performance of Afrikaans first language students who attended Afrikaans lectures and Afrikaans first language students who attended English lectures. By factoring out some of the influences of cultural background, previous exposure to mathematics education, and the mathematical ability of students (using a co-variate), a presumably fair comparison was drawn.

As secondary objectives, the following comparisons were made:

- the performance of all students who received first language lectures with that of all students who attended second language lectures; and
- the performance of all non-Afrikaans first language students (mainly African) attending English second language lectures with that of all the Afrikaans first language students attending English lectures (that is, comparing the performance of two groups of second language learners).

Research Design

The sample was a group of 836 engineering students enrolled in 2002 and 2003. It should be noted that the students used the same English textbook, irrespective of their first language, and that some of the students who attended second language formal lectures had the opportunity to attend first language tutorials.

For the analyses, the students were grouped according to their home language and the language in which they attended the formal lectures.

A grade 12 mathematics mark (Y) and a final first semester mathematics mark (X) were obtained from records and assigned to each student. The final mark in the first semester mathematics course was the dependent variable in the analyses and the grade 12 mathematics mark was the co-variate in the ANCOVA (analysis of co-variance). It is assumed for ANCOVA that all the information contained in the co-variate is also contained in the dependent variable (e.g., academic ability and educational history). However, the dependent variable also contains information on other variables. These are variables that contain information of elements that only come into play during tertiary mathematics (e.g., lectures attended).

ANCOVA tests for differences in adjusted means (i.e., the means of the dependent variable after the influence of the co-variate has been removed) and relies on the assumption that the data sets are homogeneous (Wildt & Olli, 1978). In cases where this condition is not met, ANOVA tests for difference in the observed means were performed since these tests do not rely on the assumption of homogeneity. A 5% level of statistical significance (α) was used.

The abbreviations used in the reporting of the results are shown in Table 2.

Table 2
Abbreviations used in the study

Description	Abbreviation
Afrikaans first language students attending Afrikaans (first language) lectures	A_1
Afrikaans first language students attending English (second language) lectures	A_2
English first language students attending English (first language) lectures	E_1
Other first language students attending English (second language) lectures	B_2
All students attending first language lectures	$F = A_1 \cup E_1$
All students attending second language lectures	$S = A_2 \cup B_2$

Group A_2 consisted mainly of students who had timetable clashes and a (small) number of Afrikaans first language students who preferred to attend English lectures. This study was mainly concerned with comparing the adjusted mean results of groups A_1 and A_2. These two groups were of interest because their home languages were the same and yet one group received first language tuition and the other second language tuition. However, since data on groups E_1 and B_2 were also available, we decided to include the groups in our analyses. Group B_2 consisted mainly of African and a few Asian students. Indian students were regarded as belonging to Group E_1.

Groups F and S were constructed by grouping together all students attending first language lectures and all students attending second language lectures, respectively. The latter grouping involved students with a variety of home languages and so could provide a view of the influence of second language instruction on achievement in tertiary mathematics for a fairly representative group of the population of South Africa.

Statistical Analysis

Details of the composition of the sample, with respect to group and year of enrolment, are reported in Table 3. First year engineering students from 2002 and 2003 are included in the sample.

Table 3
Group sizes by year of enrolment

	A_1		A_2		E_1		B_2		Total	
Year	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
N	129	337	3	25	40	125	41	136	213	623

Roughly a quarter of the students in the sample were taken from the 2002 first year group. More than half of the students in the sample came from the population of Afrikaans first language students attending Afrikaans lectures (A_1). The composition of group B_2 is shown in Table 4.

Table 4
Group B_2 composition by year of enrolment

	2002	2003
African	32	121
Other (including Japanese, Chinese and French)	9	15

In general the African students in group B_2 have much the same mathematical background as they were instructed in English, their second language, at the secondary mathematics level. These students also share similar social and economical backgrounds. There is reasonable similarity in the different African languages spoken by the members of group B_2 – they can communicate with each other to an extent. Consequently, group B_2 can be assumed to be a relatively homogeneous group. The statistical property of homogeneity refers to the property of two or more pairs of data sets having the same regression coefficient (Wildt & Olli, 1978). In statistical terms this means that the regression coefficients of the linear fit of each of the pairs of data sets do not differ significantly. In order to determine which populations were homogeneous with regard to the grade 12 mathematics mark (Y) and the final first semester mathematics mark (X), hypothesis tests for equal population regression coefficients were performed. The sample regression coefficients are given in Table 5.

Table 5
Regression coefficients

A_1	A_2	E_1	B_2	F	S	Total
0.561	0.39	0.496	0.58	0.527	0.385	0.511

The outcome of a hypothesis test is based on the value of the exceedence probability (p) relative to the significance level (α). The p-value is the probability that the test statistic will be equal to or more extreme than the computed test statistic, based on the observed data set and conditional on the null-hypothesis being true. The α level is the probability of rejecting the null-hypothesis when in actual fact it should have been accepted (thus, in a certain sense, it is the probability of making an incorrect conclusion). These values should be interpreted as follows: If the p-value exceeds the α-level, the null-hypothesis is not rejected; if the p-value is less than the α-level, the null-hypothesis is rejected.

The p-values obtained in the test for equal population regression coefficients are given in Table 6. The null-hypothesis of equal regression coefficients is rejected if a p-value less than $\alpha = 0.05$ is obtained.

Table 6
p-values for hypothesis tests for equal regression coefficients

	A_1, A_2, E_1, B_2	A_1, A_2	A_2, B_2	A_1, E_1	F, S	F, B_2
p	0	0.671	0.068	0.029	0.995	0

$\alpha = 0.05$

The tests for equal regression coefficients reveal that due to non-homogeneity A_1, A_2, E_1 and B_2 cannot be compared simultaneously (Table 6). Neither can groups F and B_2 and the two groups of first language learners, A_1 and E_1, be compared. Consequently, ANCOVA can only be implemented for the two groups of Afrikaans first language learners (A_1 and A_2), the two groups of second language learners (A_2 and B_2) and the combined groups of all first language students and all second language students (F and S).

In the ANCOVA procedure, the effect of a co-variate is removed from the dependent variable and the adjusted means are then compared. The adjusted sample means for the students' university mathematics performance measures and the results of the ANCOVA analyses are reported in Table 7.

Table 7
Observed and adjusted means, as well as p-values, for the ANCOVA analysis

Group	A_1	A_2	A_2	B_2	F	S
Mean	62.55	61.07	61.07	59.07	61.28	59.35
Adjusted mean	62.75	57.73	60.68	59.56	61.02	60.17
p	0.018		0.494		0.361	

$\alpha = 0.05$

The ANCOVA results (Table 7) indicated that there was a significant difference in the university level mathematics performances of the group A_1 and group A_2 students.

Since non-homogeneity prohibited the use of ANCOVA for some group comparisons, ANOVAs were conducted on the mean grade 12 mathematics measures (Y) and on the first semester calculus (X) results across the four groups to establish whether there were differences. ANOVA is not as powerful a statistical test as ANCOVA in that it does not take into account the influence of a co-variate. Still, ANOVAs were conducted on the dependent variable (university calculus results) and the co-variate (grade 12 results) and the results were interpreted in combination . It is important to note that because of this combined interpretation of the ANOVA hypothesis test results, each with a significance level of 5%, the conclusions are based on a significance level of only 10%. The ANOVA-results are presented in Table 8.

Table 8
p-values for the ANOVA analysis

	A_1	A_2	E_1	B_2	p-value
Mean (Y: Grade 12 performance)	72.794	77.107	71.479	69.847	0.007
Mean (X: Calculus scores)	62.547	61.071	57.703	59.073	0.001

$\alpha = 0.05$

The ANOVA results (Table 8) indicate that there were at least two differing means for each of the two variables. The actual differing means were identified using the unrestricted least significant difference (LSD) method (Saville, 1990). To retain a significance level of 5%, a Bonferonni adjustment was applied and thus the post hoc comparison tests were performed at a significance level of 0.8%. The results are shown in Table 9. Only results of relevant comparisons are included.

Table 9
p-values for LSD post hoc comparison tests

	A_1, A_2	A_1, B_2	E_1, B_2
Mean (Y: Grade 12 performance)	0	0	0.105
Mean (X: Calculus scores)	0.306	0.117	0.195

$\alpha = 0.008$

The post hoc comparison tests (Table 9) following the ANOVAs revealed that there was no significant difference in the average performance in first year calculus of A_1 and A_2 students, although they differed significantly in their mean school mathematics achievement, with A_2 students stronger in secondary mathematics than A_1 students. The "decline" in performance of A_2 students in tertiary calculus might be due to a lack of proficiency in the second language instruction medium. This result would support that of Mestre (1981) who reported a significant positive correlation between problem solving and language proficiency of Hispanic college students. Note that there are many extraneous influences that have not been accounted for, such as factors regarding the lecturer and tutor, which may also explain this result.

A_2 students seemed to perform better at school level mathematics than did the B_2 students (Tables 8 and 9). However, at tertiary level, the two groups did not differ significantly (Table 9). This could either be due to a lowered tertiary achievement by A_2 students or an improvement in achievement by the B_2 students. We favour the explanation that a decrease in A_2 achievement accounts for the result of the comparison between groups A_2 and B_2. Note that in the ANCOVA tests these two groups did not differ significantly with respect to their adjusted means (Table 7). Since ANCOVA-results are more powerful than ANOVAs and a significance level of 5% can be used, we ultimately favour a conclusion of no significant difference in the mean Calculus scores of groups A_2 and B_2. However, we strongly suggest that further investigation should be undertaken with respect to these two groups. The results of the pair-wise comparison between A_2 and E_1 students' achievements indicated a decrease in the performance of the A_2 students relative to that of the E_1 students.

The ANCOVA result of insignificant differences between students in groups S and F (Table 7) is explained by the ANOVA result which indicates that the mean score for students in group B_2 (who make up a significant part of group S) did not differ significantly from that of students in E_1 (Tables 8 and 9).

There was no significant difference in the performances of E_1 students and B_2 students for secondary or tertiary mathematics (Table 9). Again, the result of the school mathematics comparison was maintained in the university calculus comparison. This result is to be expected, since both of these groups are exposed to the same instruction language at both educational levels.

Discussion

When starting out on this research project we had a number of intuitively conceived notions, based on our South African heritage and having witnessed the political transition of the past few years. These included:

1. Afrikaans students, because of their high level of bilingualism would cope well with second language instruction and should not be at a disadvantage to fellow students who receive first language instruction.
2. African students receive their secondary teaching in English and one could expect them to be more *cognitively bilingual* (know mathematical English) (Cummins, 1978) than Afrikaans first language students who receive their secondary teaching in Afrikaans. One would expect that the African students therefore have an advantage over Afrikaans speaking students who are perhaps more *linguistically bilingual* (know colloquial English).
3. The *linguistic distance* (Dawe, 1983) between African languages and English is greater than the distance between Afrikaans and English, since Afrikaans is a European language (similar to Dutch). This could lead us to expect the African students to be disadvantaged compared to Afrikaans speaking students when it comes to second

language instruction. The suggestion stands in direct contrast to the second supposition.

4. In general, most students in South Africa have an adequate command of English and would not be disadvantaged by second language instruction.

We were wrong in the first case. There was a statistically significant difference in the performance of the Afrikaans students attending Afrikaans lectures and the Afrikaans students attending English lectures (the former outperforming the latter). This conclusion is based on the results of two statistical analyses. Why this is the case could possibly be explained from within the South African context. Afrikaans students receive their secondary schooling in Afrikaans and are linguistically bilingual but not necessarily cognitively bilingual. Our research then indicates that linguistic bilingualism is not sufficient for ensuring achievement in mathematics. This agrees with the findings of Barton and Neville-Barton (2003) who regard proficiency in mathematical English as an important factor.

Suppositions 2 and 3 conflict. Afrikaans-speaking students are possibly more linguistically bilingual than the African students as inferred and discussed before. (It has to be emphasised that this situation is rapidly changing as the effect of the new political dispensation is manifesting itself). African students are more cognitively bilingual. The greater "distance" between African languages and English than between Afrikaans and English would, on the other hand, lead one to expect better performance of the Afrikaans-speaking students than of the African students. The research shows that there is no difference in the performance of the two groups of second language learners (Afrikaans and other – mainly African). This result was based on relatively small samples and it is suggested that more investigation be performed before making definite conclusions with respect to these two groups. Since the two different scenarios described in suppositions 2 and 3 could cancel each other out, it is unfortunately not possible to draw any conclusions in this regard.

Our empirical investigation seemed to support the fourth supposition. Indeed, the result of insignificant difference in performance of the group of first language students and the group of second language students, suggests that in general, post secondary students attending English second language lectures in South Africa have an adequate understanding of English (be it conversational English or mathematical English). It may also suggest that generally speaking, proficiency in the language of instruction does not have as big an influence on performance in tertiary calculus as it may have had in earlier years of study.

Supporting the fourth supposition, and seemingly contradictory to the result in the comparison of the two groups of Afrikaans first language students, is the result that there is no significant difference in the performance of the group of all students attending first language lectures (Afrikaans and English) and the group attending second language lectures

(Afrikaans and African students attending English lectures). Although there is a difference in performance between the two groups of Afrikaans first language students, the difference is marginal and is verified only at a 5% level, not at a 1% level. Doubt is also cast on this difference because of the small group size of the group taught in English, compared with the group taught in Afrikaans. When these two groups are combined to form the larger groups of all first and all second language students, the effect of the difference is marginalised. In general, the ANCOVA result of insignificant difference in the performances of these two groups supports the idea that proficiency in everyday English is not necessarily predictive of mathematics achievement. This result supports that of De Avila (1980) who concluded that (English) language proficiency of Hispanics was not strongly predictive of mathematics achievement. It also supports the conclusion of Barton and Neville-Barton (2003) that ability in mathematical English is more important than ability in colloquial English.

Various shortcomings limited the study. Increasing the sample sizes (especially in the case of group A_2) and controlling all extraneous variables (like the tutor whose sessions the students attend) should address many of the limitations. However, this would mean forcing students to attend lectures in a particular language (which would be unfair to these students). Shortcomings in the analysis are primarily due to the shortage of data and inconsistencies in analysis procedures and certain characteristics (e.g., non-homogeneity) of the data that prohibit the usage of certain statistical procedures. We expand for clarification:

- Many of the students attending first language tutorials, also attended second language lectures. This can remove some of the effect of second language learning on students' performances.
- Group A_2 may not be representative of the population of Afrikaans students, since these students could be the academically stronger students (especially with respect to grade 12 mathematics marks).
- A_2 students in this sample may be more proficient in English than the majority of the Afrikaans student population; an influence not assessed due to the absence of such data.
- Four different lecturers were involved. The influence of the different lecturers on students' performances was not taken into account.
- The lecturers teaching the English classes were all second language English speakers.
- A total of 11 students repeated the course, two of whom are second language learners (B_2). The influence of this factor on the analysis was considered to be negligible.
- Indian students were regarded as English first language students. Data on the number of Indian students were not available, and as such we could not determine the influence of this group.

- The non-homogeneity of the data does not allow for all the adjusted mean comparisons originally planned for in the study. More and bigger samples may solve this problem and might perhaps give more conclusive results.
- The assumption that each of the groups was relatively homogeneous (or that ANCOVA removes diversity within each of the sample groups) was not tested.

To conclude, when Afrikaans students who attend English lectures were compared with cultural peers in the South African context (Afrikaans and English students) who attend first language lectures, they perform significantly worse; when Afrikaans first language students were compared to African students, there seemed to be no significant difference in performance. The comparison of the entire group of second language students and the entire group of first language students in South Africa indicated that there was no significant difference; however, it is important to keep in mind that there was still a lot of inherent variability in these two groups.

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