The influence of second language teaching on undergraduate mathematics performance

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Abstract

Understanding abstract concepts and ideas in mathematics, if instruction takes place in the first language of the student, is tough as it is. Yet worldwide it is a recognised problem that 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 – have to face this difficulty. In a quantitative study of first year calculus students, we investigate two groups of students. For one group tuition takes place in their home language; for the second group, tuition is in English, a second or even a third language. By factoring out the influence of various social factors as well as the mathematical backgrounds of students, more insight is gained into the success of the teaching process.

Two groups of students attending first language lectures are identified: Afrikaans and English. Two groups of students attending English second language lectures are identified: Afrikaans and other (consisting mainly of students from African cultures). A grade twelve mathematics mark and a first year mathematics mark are associated with each research participant. Where possible, analysis of co-variance (ANCOVA) is done to compare the adjusted means of the different groups. The observed means of the groups are compared in the analysis of variance (ANOVA).

The study shows that there is no significant difference between the adjusted means of the entire group of first language learners and the entire group of second language learners. Neither is there any statistically significant difference between the performances of the two groups of second language learners (based on the adjusted means).

Introduction

Mastering undergraduate mathematics is sometimes considered to be a two-step process: Firstly, students have to understand the mathematical concepts (Richards, 1982; Thurston, 1995) and secondly, 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, etc.). Still, we use 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.
- The student’s ability to understand and communicate abstract concepts when translated into written mathematics.

The purpose of this article is to report on the findings of a quantitative study on the influence of second language learning on students in South Africa.

**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.

Less 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 is given in Table 1.

**TABLE 1: South Africa: Home language distribution (2001)**

<table>
<thead>
<tr>
<th>Home language</th>
<th>% of population</th>
</tr>
</thead>
<tbody>
<tr>
<td>IsiZulu</td>
<td>23.8</td>
</tr>
<tr>
<td>IsiXhosa</td>
<td>17.6</td>
</tr>
<tr>
<td>Afrikaans</td>
<td>13.3</td>
</tr>
<tr>
<td>Sepedi</td>
<td>9.4</td>
</tr>
<tr>
<td>Setswana</td>
<td>8.2</td>
</tr>
<tr>
<td>English</td>
<td>8.2</td>
</tr>
<tr>
<td>Sesotho</td>
<td>7.9</td>
</tr>
<tr>
<td>Xitsonga</td>
<td>4.4</td>
</tr>
<tr>
<td>SiSwati</td>
<td>2.7</td>
</tr>
<tr>
<td>Tshivenda</td>
<td>2.3</td>
</tr>
<tr>
<td>IsiNdebele</td>
<td>1.6</td>
</tr>
<tr>
<td>Other</td>
<td>0.5</td>
</tr>
</tbody>
</table>

South African universities and their governing bodies decide on policies concerning the language(s) in which lectures are presented. The outcome of this and
similar studies should contribute to making informed decisions on this issue. Many of the traditionally Afrikaans medium universities (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 twelve students of 2002 (Mboweni-Marais, 2003), it is 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 are dissatisfied with this shift in teaching medium from Afrikaans to English. They believe 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 – separate 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 double-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, the initial study on the influence of second language tertiary mathematics teaching in South Africa.

**Literature Review**

Much research has been conducted on the effect of second language teaching in elementary and secondary mathematics education (Adler, 1998; Cocking and Chipman, 1988; De Avila, 1988; Leap, 1988). However, little research has been done in the field of second language teaching of university mathematics. Barton and Neville-Barton's article (2003) 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 influence 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:

1. Entry characteristics of the learner
2. Educational opportunities provided to the learner and
3. Motivation to learn.

We list some of the specific factors cited in literature as influencing academic performance:

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

These factors do not necessarily belong to only one of the three categories mentioned by Cocking and Chipman. For instance, a student's culture may cause him/her to be at 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, stating that:

There is a complex interaction between language features, context features, mathematical knowledge and use of symbols. (p. 27)

This interaction makes it very difficult to view the role of language in mathematics learning in isolation. Complicating the matter even more is the fact that conclusions of different studies sometimes contradict each other, as is the case with De Avila (1980) and Mestre (1981). In a study of grade 1, 3 and 5 Hispanic students, De Avila finds that language proficiency is not strongly predictive of mathematics achievement but Mestre reports significant positive correlation between problem solving and language proficiency of Hispanic college students. These studies are referred to by Cocking and Chipman (1988, p.25).

Focussing our attention on understanding the role of language in mathematics learning, we analyse 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 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 suggests that effective communication of mathematical ideas is the key. Language forms an integral part of this communication. McLean (2000) supports this in saying that

Many of the learning problems of students originate from an inadequate knowledge of the basic vocabulary.

Bohlmann (2001) also discusses 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) rightly states 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 instruction medium is 5 000 words. She claims 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 get formal exposure to English from the first grade and they complete the English second language curriculum up to grade twelve. 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 (Rollnick, 2000; Bohlmann, 2001).

Referring to the first part of the point of departure mentioned in the introduction, 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) regard proficiency in mathematical English to be a more important factor than proficiency in general English in the learning of university mathematics.

The second part of the point of departure, mentioned in the introduction, refers to the students’ ability to communicate mathematics in a written format. The written mathematics includes the genres of proof, definitions and theorems (Marais, 2000; Lemke, 1990; Wheeler and Wheeler, 1979). Students need to learn to formalise mathematical concepts, using mathematical text and symbols. Cocking and Chipman (1988) refer to Spencer and Russell (1960), who claimed that the difficulties in reading mathematics are due to the specialised language used 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 also refer to studies by Rosnick and Clement (1980); Clement, Lochhead and Monk (1981); Kaput and Clement (1979); and Rosnick (1981). They all
report on the widespread inability of university engineering students to translate relationships expressed in natural language into corresponding mathematical expressions and vice versa.

When one considers that fluent reading and understanding of mathematical text and symbolism are essential for studying textbooks, the importance of proper mathematical literacy becomes even more evident (O’Toole, 1996).

Barton and Neville-Barton (2003) in their study of 83 volunteer first year students conducted in January 2003, found that because of a lack of understanding of mathematical text, students who have English as an additional language (EAL students) are at a 10% disadvantage in comparison with English first language students. (The EAL students in their study were mainly Asian.) They also found that although written mathematics can take the form of text, symbols, diagrams or graphs, second language students prefer mathematical symbols to express themselves to texts, diagrams or graphs, especially in the case of text questions. However, EAL students' reliance on symbolism in mathematics learning is unjustified, showing that mathematics is not language free.

To conclude, it should be added that poor ability to communicate mathematics could be the result, rather than the cause, of poor understanding (Bohlmann, 2001).

The literature review underlines the notion that language is one of many factors that play a part in learning mathematics and that reliance on symbols alone is not enough. The disadvantage of second language learners over first language learners at university level as researched by Barton and Neville-Barton (2003) needs to be investigated in the South African context.

Objectives

In this study we begin to explore the influence of second language mathematics teaching on the diverse population of second language tertiary students in South Africa. In this, the first phase of our research, we investigate the hypothesis that Afrikaans first language students in the context of this paper have sufficient understanding of English to successfully complete a tertiary mathematics course.

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

As secondary objectives, the following comparisons are made:

- the performance of all students who receive first language lectures with that of all students who attend second language lectures.
- 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 is a group of 836 engineering students of 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 analysis, the students are grouped according to their home language and the language in which they attended the formal lectures.

A grade twelve mathematics mark ($Y$) and a final first semester mathematics mark ($X$) are assigned to each student. The final mark in the first semester mathematics course is the dependent variable in the analysis and the grade twelve mathematics mark is the co-variate in the ANCOVA (analysis of co-variance).

ANCOVA tests for difference in adjusted means and relies on the assumption that the data sets are homogeneous. This means that for each group of means being compared in the ANCOVA analysis, the slopes of the least squares linear fits on the scatter plot of $Y$ vs. $X$ have to be the same. In cases where this condition is not met, ANOVA tests for difference in the observed means are performed. A 5% level of significance ($\alpha$) is used.

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

<table>
<thead>
<tr>
<th>TABLE 2: Abbreviations used in the study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
</tr>
<tr>
<td>Afrikaans first language students</td>
</tr>
<tr>
<td>attending Afrikaans (first language)</td>
</tr>
<tr>
<td>lectures</td>
</tr>
<tr>
<td>Afrikaans first language students</td>
</tr>
<tr>
<td>attending English (second language)</td>
</tr>
<tr>
<td>lectures</td>
</tr>
<tr>
<td>English first language students</td>
</tr>
<tr>
<td>attending English (first language)</td>
</tr>
<tr>
<td>lectures</td>
</tr>
<tr>
<td>Other first language students</td>
</tr>
<tr>
<td>attending English (second language)</td>
</tr>
<tr>
<td>lectures</td>
</tr>
<tr>
<td>All students that attend first language</td>
</tr>
<tr>
<td>lectures</td>
</tr>
<tr>
<td>All students that attend second language</td>
</tr>
<tr>
<td>lectures</td>
</tr>
</tbody>
</table>

Group A2 consists mainly of students who have timetable clashes and a (small) number of Afrikaans first language students who prefer to attend English lectures (either because they attended English medium high schools or because they believe that it will make the adjustment to the work environment easier). The influence of the latter is not investigated, since data are not available. Indian students are regarded as belonging to Group E1. Group B2 consists mainly of African and a few Asian students.

**Statistical Analysis**

Details on the composition of the sample with respect to group and year are reported in Table 3 and Table 4. In this sample, only part of the 2002 group and the entire 2003 group of first year engineering students is included.
TABLE 3: Group sizes

<table>
<thead>
<tr>
<th></th>
<th>A_1</th>
<th>A_2</th>
<th>E_1</th>
<th>B_2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>129</td>
<td>337</td>
<td>3</td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>136</td>
<td>136</td>
<td>111</td>
<td>111</td>
<td>213</td>
</tr>
</tbody>
</table>

Roughly a quarter of the students in the sample are taken from the 2002 first year group and more than half of the students in the sample come from the population of Afrikaans first language students attending Afrikaans lectures (A_1).

TABLE 4: Groups that constitute B_2

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>African</td>
<td>32</td>
<td>121</td>
</tr>
<tr>
<td>Other (including Japanese, Chinese and French)</td>
<td>9</td>
<td>15</td>
</tr>
</tbody>
</table>

The majority of the students in group B_2 are from the African community. The African students in the sample are mostly from the Zulu, Xhosa, Sotho, Tswana, Tshongha and Venda cultures.

The homogeneity of various combinations of data sets has to be determined. Therefore, hypothesis tests for equal regression coefficients of different populations are performed. These tests are based on the observed regression coefficients, which are given in Table 5.

TABLE 5: Regression coefficients

<table>
<thead>
<tr>
<th></th>
<th>A_1</th>
<th>A_2</th>
<th>E_1</th>
<th>B_2</th>
<th>F</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>0.561</td>
<td>0.39</td>
<td>0.496</td>
<td>0.58</td>
<td>0.527</td>
<td>0.385</td>
<td>0.511</td>
</tr>
</tbody>
</table>

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, conditioned on the null hypothesis being true. This is also sometimes referred to as the exceedence probability. In my report on the hypothesis tests, I only give the p-values associated with each hypothesis test. This value should be interpreted as follows: If the p-value exceeds the \( \alpha \)-level, the null-hypothesis is not rejected; if the p-value is less than the \( \alpha \)-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 0.05 is obtained.
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. 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 done 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 are reported in Table 7.

The p-values for hypothesis tests for equal adjusted means are given in Table 8.

**TABLE 6: p-values for hypothesis tests for equal regression coefficients**

<table>
<thead>
<tr>
<th>A_1, A_2, E_1, B_2</th>
<th>A_1, A_2</th>
<th>A_2, B_2</th>
<th>A_1, E_1</th>
<th>F, S</th>
<th>F, B_2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$</td>
<td>0</td>
<td>0.671</td>
<td>0.068</td>
<td>0.029</td>
<td>0.995</td>
</tr>
</tbody>
</table>

$\alpha = 0.05$

**TABLE 7: Observed and adjusted means in ANCOVA analysis**

<table>
<thead>
<tr>
<th>Group</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_2$</th>
<th>$B_2$</th>
<th>$F$</th>
<th>$S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>62.55</td>
<td>61.07</td>
<td>61.07</td>
<td>59.07</td>
<td>61.28</td>
<td>59.35</td>
</tr>
<tr>
<td>Adj Mean</td>
<td>62.75</td>
<td>57.73</td>
<td>60.68</td>
<td>59.56</td>
<td>61.02</td>
<td>60.17</td>
</tr>
</tbody>
</table>

The p-values for hypothesis tests for equal adjusted means are given in Table 8.

**TABLE 8: p-values for the ANCOVA analysis**

<table>
<thead>
<tr>
<th>A_1, A_2</th>
<th>A_2, B_2</th>
<th>F, S</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$</td>
<td>0.018</td>
<td>0.494</td>
</tr>
</tbody>
</table>

$\alpha = 0.05$

ANCOVA indicates that there is a significant difference in performances of $A_1$ and $A_2$ students. However, had a significance level of 1% been implemented, the hypothesis of equal adjusted means would not have been rejected ($p = 0.018$). Therefore, although this test shows that these two groups differ, the statistical result is not very convincing. Alternative tests and more investigative studies are needed to confirm this result. As a second resort, I do ANOVA tests on the data as well. These are discussed later in this section.

There seems to be no significant difference when the entire group of second language learners ($S$) is compared with the entire group of first language students ($F$). This result seems to contradict the one of difference in performance of $A_1$ and $A_2$ students. However with regards to the composition of $S$, the size of group $B_2$ is considerably greater than that of group $A_2$, so that the overall figure is in actual fact more representative of $B_2$ students than it is of $A_2$ students. The reason for this
A seemingly contradictory result is sought in the ANOVA-analysis. In general, the ANCOVA-result of insignificant difference in the performances of groups F and S supports the idea that in fact proficiency in mathematical English and written mathematics is more predictive of mathematics achievement than proficiency in the everyday English. This result supports that of De Avila (1980) who concludes that language proficiency of Hispanics is 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.

There are two reasons for also implementing ANOVA-analyses: non-homogeneity prohibits the use of ANCOVA in many of the group comparisons and ANCOVA does not give a very significant result on the comparison of A₁ and A₂. ANOVA is performed on the mean grade twelve mathematics (\(Y\)) and first year calculus (\(X\)) results respectively to establish whether they differ. The ANOVA tests are not as strong as the ANCOVA tests in that these procedures do not take into account the influence of a co-variate. Still, I perform ANOVA tests on both the dependent variable and the co-variate and combine the results of the two ANOVA tests in my interpretation. 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 given in Table 9.

**TABLE 9: p-values for the ANOVA analysis**

<table>
<thead>
<tr>
<th></th>
<th>A₁</th>
<th>A₂</th>
<th>E₁</th>
<th>B₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ((Y))</td>
<td>72.794</td>
<td>77.107</td>
<td>71.479</td>
<td>69.847</td>
</tr>
<tr>
<td>(p = 0.007) &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ((X))</td>
<td>62.547</td>
<td>61.071</td>
<td>57.703</td>
<td>59.073</td>
</tr>
<tr>
<td>(p = 0.001) &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(F(\alpha;3,832) \alpha = 0.05\)

Since the p-value for both of the variables investigated is less than 5%, there are indeed at least two differing means in each of the two variables. The actual differing means are identified using the unrestricted least significant difference (LSD) method (Saville, 1990). To retain a significance level of 5 %, a Bonferonni adjustment is applied and thus the post hoc comparison tests are done at a significance level of 0.8 %. The results are given in Table 10.

**TABLE 10: p-values for LSD post hoc comparison tests**

<table>
<thead>
<tr>
<th></th>
<th>A₁, A₂</th>
<th>A₁, E₁</th>
<th>A₁, B₂</th>
<th>A₂, E₁</th>
<th>A₂, B₂</th>
<th>E₁, B₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Y: p)</td>
<td>0</td>
<td>0.058</td>
<td>0</td>
<td>0.178</td>
<td>0</td>
<td>0.105</td>
</tr>
<tr>
<td>(X: p)</td>
<td>0.306</td>
<td>0</td>
<td>0</td>
<td>0.031</td>
<td>0.117</td>
<td>0.195</td>
</tr>
</tbody>
</table>

\(F(\alpha;3,832) \alpha = 0.008\)
The ANOVA investigation reveals that on a 5% significance level, there is no difference in the average performance in first year calculus of A₁ and A₂ students. However, these groups seem to differ significantly in their mean school mathematics achievement, in that the A₂ students are actually stronger in secondary mathematics than A₁ students. Therefore the A₂ students actually outperformed the A₁ students on first year university calculus level and the decline in performance of A₂ students in tertiary calculus might actually be due to a lack of proficiency in the second language instruction medium. This result supports that of Mestre (1981) who reports 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.

The performances of A₁ and E₁ students in school mathematics do not differ significantly, but at tertiary level A₁ students seem to do significantly better than E₁ students. This may be the result of some uncontrolled extraneous variable, which only come into play at the university level of mathematics. The fact that most of the lecturers who teach in English themselves are in actual fact Afrikaans first language speakers, might explain this result.

There is a difference in the performances of A₁ and B₂ students at secondary mathematics level. This difference is maintained in their first year university calculus performances. This conservation of difference in performance is to be expected, since both these groups are exposed to the same instruction-medium at both levels of mathematics.

Although students in group A₂ perform significantly better in high school mathematics than the E₁ students do, there is no significant difference in their tertiary calculus achievements. Thus, in actual fact the A₂ students perform worse than the E₁ students do at tertiary calculus level. This could again support the notion that the A₂ students are at a disadvantage since, although they seem to be the better performers of the two groups of students, their calculus achievement at tertiary level do not differ significantly from that of the E₁ students. Again there may be some other extraneous variable, which is not accounted for in the analysis, which may have caused this result.

A₂ students seem to perform better at school level mathematics than the B₂ students do. However, at tertiary level, the two groups do not differ significantly. This could either be due to poorer achievement of A₂ students or an improvement in achievement by the B₂ students. The result of the pair-wise comparison between A₂ and E₁ indicates a decrease in the performance of the A₂ students relative to that of the E₁ students so that we would favour the explanation that a decrease in A₂ achievement accounts for the result of the comparison made between A₂ and B₂. Note that in the ANCOVA-tests these two groups do not differ significantly with respect to their adjusted means. Since the ANCOVA-results are stronger and implement a significance level of 5%, we would ultimately favour a conclusion of no significant difference. However, we strongly suggest that further investigation should be done with respect to these two groups.

The ANCOVA-result of insignificant difference between S and F is explained by the ANOVA-result, which indicates that B₂ (which makes out a significant part of S) and E₁ do not differ significantly.
There is no significant difference in the performances of E₁ students and B₂ students either with respect to secondary or tertiary mathematics. Again the result of the school mathematics comparison is 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.

**Conclusion**

What is the extent of the linguistic disadvantage of South African second language students? We focussed our study on Afrikaans first language students and performed various statistical techniques on secondary and tertiary mathematics results. Also, some insight is gained on the performance of African second language students. There seems to be a statistically significant difference in the performances of the Afrikaans students attending Afrikaans lectures and Afrikaans students attending English lectures. This conclusion is based on the results of two statistical analyses. It seems that although the Afrikaans students that attend English lectures are academically stronger than the Afrikaans first language students that attend Afrikaans lectures, there is no difference in performance between the two groups. This supports the findings of Barton and Neville-Barton (2003) and Mestre (1981) that second language students are at a disadvantage to first language students. It is suggested however that more investigation be done before making definite conclusions with respect to these two groups.

There is no notable 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). This result is reasonable, since South African scholars get a considerable amount of formal training in English. South Africans are also increasingly exposed to English in everyday life, where they are often required to interact both formally and informally in English. This result suggests that students attending English second language lectures in South Africa have an adequate understanding of English (be it general conversational English or mathematical English), especially in the case of African EAL students. It may also suggest that proficiency in the language of instruction does not have as big an influence on performance in tertiary calculus as proficiency in written or verbal mathematics might have. Indeed, the findings of the study conducted by Clements and Lean (1981) indicate that students handle word-free (e.g. symbolic, graphical) questions with more ease than they do verbally presented arithmetic problems. Also, Clarkson (1991) attributes the poor performance of Papua New Guinea scholars to poor mathematical vocabulary.

There is no difference in the performances of the two groups of second language learners (Afrikaans and other - mainly African). This result was based on two relatively small samples (compare the sample size of the group of Africans with that of the group of Afrikaans students attending Afrikaans lectures). However, it suggests that none of these two groups are more likely to be disadvantaged by second language instruction in first year tertiary calculus when intellectual ability and mathematics background are taken into account. This finding also supports the notion that proficiency in everyday English may not be as much of a prerequisite for mathematics achievement as proficiency in mathematical English and written mathematics may be. In their study of
the achievements of university mathematics students, Barton and Neville-Barton (2003) regard proficiency in mathematical English as an important factor. Their conclusion is supported by the result of this analysis.

Various shortcomings limited the study. Increasing the sample sizes (especially in the case of group A2) and controlling all extraneous variables (like the tutor session 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 towards these students). Shortcomings in the analysis are primarily due to the shortage of data, bias 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 attend first language tutorials, although attending second language lectures. This removes some of the effect of second language learning on students' performances.

• Group A2 may not be representative of the population of Afrikaans students, since these students could be the academically stronger students (especially referring to grade twelve mathematics marks).

• A2 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 are involved. The influence of the different lecturers on students' performances is not taken into account.

• A total of eleven students repeat the course; two of which are second language learners (B2). The influence of this factor on the analysis is considered to be negligible.

• Indian students are regarded as English first language students. Data on the number of Indian students were not available, and as such we cannot determine the influence of this group.

• The non-homogeneity of the data does not allow for all the adjusted mean comparisons originally planned for the study. More and bigger samples may solve this problem and might perhaps give more conclusive results – especially if one considers the small sample size of A2.

• The assumption that each of the groups is relatively homogeneous (or that ANCOVA removes diversity within each of the sample groups) is risky.

To conclude, when Afrikaans students who attend English lectures are 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 are compared to African students, there seems 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 indicates that
there is no significant difference; however, it is important to keep in mind that there is still a lot of inherent variability in these two groups.

References


