EXPLORING THE ENGLISH PROFICIENCY-MATHEMATICAL PROFICIENCY RELATIONSHIP IN LEARNERS: AN INVESTIGATION USING INSTRUCTIONAL ENGLISH COMPUTER SOFTWARE

Essien Anthony and Setati Mamokgethi
Marang Wits Centre for Maths and Science Education
University of the Witwatersrand

The difficulty of teaching and learning mathematics in a language that is not the learners’ home language (e.g. English) is well documented. It can be argued that underachievement by South African learners in most rural schools is due to a lack of opportunity to participate in meaningful and challenging learning experience (sometimes due to lack of proficiency in English) rather than to a lack of ability or potential. This study investigated how improvement of learners’ English language proficiency enables or constrains the development of mathematical proficiency. English Computer software was used as intervention to improve the English Language proficiency of 45 learners. Statistical methods were used to analyse the pre- and post-tests in order to compare these learners with learners from another class of 48. The classroom interaction in the mathematics class before and after the intervention was analysed in order to ascertain whether or not the mathematics interaction has been enabled or constrained. The findings of this study were that, first, any attempt to improve the language proficiency of learners with the aim of improving academic proficiency should be done in such a way as to develop concurrently, both the Basic interpersonal communicative skills and the cognitive-academic language proficiency; second, proficiency in the language of instruction (English) is an important index in mathematics proficiency, but improvement of learners’ language proficiency, even though important for achievement in mathematics, may not be sufficient to impact on classroom interaction. The teacher’s ability to draw on learner’s linguistic resources is also of critical importance.

INTRODUCTION

Research study and philosophies dealing with the relationship between language proficiency and mathematical proficiency have either positioned the one as dependent on the other (Peal & Lampert, Cummins, 1978; Baker, 1988; 1962, Bialystock, 1992, in Lyon, 1996; Clarkson, 1992; Wales, 1977; Freitag, 1997; Holton, Anderson, Thomas, and Fletcher, 1999, in Albert, 2001; Taylor 2002) or the two as autonomous (Macnamara, 1977; Chomsky, 1975; Henney, in Aiken, 1972). In South Africa, even though the constitution gives provision for learners to learn in any of the 11 official languages of their choice, most learners learn mathematics in English which for most, is not their first or home language. Underachievement in Grade 12 mathematics examinations has been found to be more prevalent amongst learners who use the English language less frequently at home (Simkins in Taylor, Muller & Vinjevold, 2003) and in areas where English is less frequently used at home.
Most research dealing with language issues in mathematics education have documented that proficiency in the language of learning and teaching is important for mathematical proficiency (e.g., Howie, 2002). But previous research into the relationship between English language proficiency and mathematics proficiency was not done in a classroom where there was an explicit attempt to improve learners’ language proficiency using computer software. The study reported here investigated how the improvement of learners’ English proficiency (using the English literacy computer software – ASTRALAB – designed to promote English proficiency) in one South African school, enabled or constrained the development of mathematical proficiency in learners. The study was organised to answer the broad question: Whether and how does improving learners’ proficiency in English enable or constrain mathematical proficiency?

**THEORETICAL ORIENTATION**

Douady (1997) contends that to know mathematics involves a double aspect. It involves firstly the acquisition, at a functional level, certain concepts and theorems that can be used to solve problems and interpret information, and also be able to pose new questions (p. 374). Secondly, to know mathematics is to be able to identify concepts and theorems as elements of a scientifically and socially recognised corpus of knowledge. It is also to be able to formulate definitions, and to state theorems belonging to this corpus and to prove them (p. 375). What role does language play in the knowing of mathematics? Pirie (1998) and Driscoll (1983) contend that mathematics symbolism is the mathematics itself and language serves to interpret the mathematics symbol. In the relationship between language and mathematics, language serves as a medium through which mathematical ideas are expressed and shared (Brown, 1997; Setati, 2005). It can be argued, as Rotman, (1993, in Ernest, 1994: 38) does, that mathematics is an activity which uses written inscription and language to create, record and justify its knowledge. Language, thus, plays an important role in the genesis, acquisition, communication, formulation and justification of mathematical knowledge – and indeed, knowledge in general (Ernest, 1994; Lerman, 2001).

It is with the above in mind that this study is informed by the socio-cultural theory of learning. The socio-cultural perspective proposes that learning is a social process and happens through participation in cultural practices (Doolittle, 1997). Learning, thus, involves becoming enculturated and enculturation into a community of practice in which a learner finds him/herself and it (learning) is marked by the use of conceptual tools like language. Since the production of mathematical knowledge, for example, involves participation and negotiation of meaning within a community of practice, it then means that the use of language as a communicative tool is integral to the process of mathematical enquiry (Siegel & Borasi, 1994). For the socio-cultural view of learning, therefore, language is essential for participation in a community of practice.

---

1 The use of this term in this study resonates with the understanding of this term as defined by Kilpatrick, Swafford & Findell (2001)
Language allows meanings to be constantly negotiated and renegotiated by members of a mathematics community – except for the mathematics register which has a fixed meaning across contexts (Brown et al; Cole and Engeström, in Chernobilsky et al, 2004).

RESEARCH DESIGN AND METHODOLOGY

In order to address the critical question above in this study, a quasi-experimental non-equivalent comparison group design was used because it was not possible to randomly assign learners to groups.

Population and Sample

The study involved a total number of ninety-three learners in grade nine. 45 learners in grade 9A constituted the experimental group while 48 learners in grade 9G constituted the control group (the number 45 and 48 are the number of learners in each respective class in the school). Learners in school offer Sesotho, IsiZulu, IsiXhosa, Setswana and Sepedi and are fluent in one or more of these languages.

The research instrument consisted of 35 questions drawn from a wide range of mathematical content and word problems which learners have covered in the class. They were made up of both multiple-choice questions and questions requiring learners to write the answers. The test items were selected from the 2003 Third International Mathematics and Science Study (TIMSS) and were modified slightly where necessary to suit the context of learners in the study.

Methods of data collection

Data from this study was collected over a period of four weeks. Before the commencement of the ASTRALAB programme in the first week, the mathematics pre-test was administered to both groups. At the end of the implementation phase (in the 4th week), the post-test was administered and the experimental class was videoed. There were class observations of the mathematics class of the experimental group at the beginning of the treatment. The mathematics class of the experimental group was also videoed a week following the end of the treatment. The video-taped mathematics lessons were used to analyse the interaction and communication in the mathematics class.

Implementation Phase of the ASTRALAB Programme

Even though the ASTRALAB programme in itself was designed to be used individually as instructional learning computer software, for implementation in the research school, an adapted version which used an inbuilt projector connected to the computer was used. This enabled whole class instruction and thereby avoided the fundamental criticism of computer based programme instruction as being an individualised approach where instructional situations are cold, mechanical and dehumanizing and where interaction between the teacher and learners is highly eclipsed (Hergenhahn & Oslon, 2001). Learners were required to participate daily in the whole class teaching using the programme for a total of 22.5 hours consisting of
30 sessions in total. In general, the software provides a unique approach to the practice and reinforcement of reading comprehension by building vocabulary, spelling, reading fluency...while testing overall comprehension.

**English Pre-test and Post-test**

On the first day of implementation, the ASTRALAB programme instructor gave learners in the experimental group a pre-test using the software. He also gave them a post test the week following the end of the implementation of the software. The results showed a 28.2% general improvement in the learners’ English proficiency from pre-test to post test.

Nieman (2006) notes that the fact that a learner understands the educator in class and is able to, with ease, read in the language of teaching and learning does not presuppose that such a learner will understand academic texts as easily and write fluently. Earlier research by Cummins (1984, in Nieman, 2006) had led him to draw a distinction between basic interpersonal communicative skills (BICS) and cognitive-academic language proficiency (CALP). While BICS denotes language proficiency in a social situation and characterised by interpersonal interaction, CALP positions itself as second level of additional language proficiency. This second level of language proficiency is what is needed if learners are to read and understand scientific reports, tasks or academic assignments in general (Nieman, 2006). From an observer point of view, it could be argued that the intervention with the ASTRALAB software, even though very interactive in nature, was biased towards the development of learners’ basic interpersonal communicative skills.

**ANALYSIS AND FINDINGS**

The data collected from the mathematics pre-test and the post-test constituted the quantitative aspect of the study while the data collected from the class observation constituted the qualitative part of the analysis.

**Analysis of pre- and post-tests**

1. A comparison of the control and experimental groups before the treatment with ASTRALAB ILS indicated that:

- In the test for skewness, there was an even distribution of learners as far as the mathematics ability is concerned (skewness = .172).
- The $t$-Test and the nonparametric test indicate that there was no statistically significant difference ($p = .29$) in the test results between the two groups before the treatment (even though there was a difference in the mean scores in favour of the experimental group).
<table>
<thead>
<tr>
<th></th>
<th>PRE-TEST RESULTS</th>
<th>POST-TEST RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MEAN</td>
<td>STD DEV</td>
</tr>
<tr>
<td>EXPERIMENTAL</td>
<td>5.4318</td>
<td>1.9813</td>
</tr>
<tr>
<td>CONTROL</td>
<td>4.9583</td>
<td>2.2874</td>
</tr>
<tr>
<td>p-value</td>
<td>t-Test: .293</td>
<td>nonparametric test: .292</td>
</tr>
</tbody>
</table>

Table 1: Statistical Results

2. Analysis of the performance in the pre-test and post-test for the control group indicated that there was no statistically significant difference ($p = .84$) between the performances in both pre-test and post-test (even though the performance of learners in this group was lower in the post-test).

3. Analysis of performance in pre-test and post-test scores for experimental group revealed a moderate correlation (.328) between performance in pre-test and performance in the post-test. A t-Test and nonparametric test indicated a statistically significant difference ($p = .03$) between scores in pre-test and those of post-test.

4. A comparative analysis of learner performance in both control and experimental groups in post-test indicate that there was a highly significant difference ($p = .008$) between performance in the experimental group compared to performance in the control group.

5. As far as the pre-test analysis by gender was concerned
   - There was no statistically significant difference between performance of boys within and across groups. This was also true of the performance by girls in the pre-test.
   - In the post-test results for gender, there was no statistically significant difference between performance by boys compared to performance by girls within the two groups.
   - There was however as statistically significant difference between the performance of girls in the experimental group and the performance of girls in the control group (there was no difference in the performance of boys across groups in the post-test).

6. As far as the content domains were concerned, there was improvement in all content domains in the experimental group but none of the domains recorded a statistically significant difference.

**Analysis of classroom interaction**

As noted in previous sections, in addition to algorithmic competence, solving word problems and using mathematical reasoning (Moschkovich, 2002), interaction in the mathematics class is also important in the teaching and learning of mathematics. If the language proficiency of learners was improved, it was also necessary to investigate whether and how much improvement of linguistic competence has either
enabled or constrained the interaction in the class. The coding system for language used by learners and the teacher distinguish when language was used either for questioning, justification, explanation, and regulation. The table below shows the talk distribution between teachers and learners:

<table>
<thead>
<tr>
<th></th>
<th>PRE-INTERVENTION</th>
<th>TOTAL</th>
<th>POST-INTERVENTION</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>English</td>
<td>African language</td>
<td>English</td>
<td>African language</td>
</tr>
<tr>
<td>TEACHER UTTERANCE</td>
<td>195</td>
<td>10</td>
<td>205</td>
<td>164</td>
</tr>
<tr>
<td>LEARNER UTTERANCE</td>
<td>179</td>
<td>-</td>
<td>179</td>
<td>157</td>
</tr>
<tr>
<td>TOTAL</td>
<td>374</td>
<td>10</td>
<td>321</td>
<td>5</td>
</tr>
</tbody>
</table>

Note that the above table tends to depict a highly interactive class for both the pre- and the post-intervention lessons. The table tends also to portray that learners talked (almost) as much as the teacher. What the table does not do is indicate the nature or quality of the talk by both the teacher and the learners. A careful study of the pre-intervention lesson and of the post-intervention lesson which takes into consideration the nature of the talk indicates that there was no difference in the interactive pattern of both lessons. What dominated the classroom interaction in both lessons was first, only teacher-learner interaction and learner-content interaction. In both lessons, there was no learner-learner interaction. Even though learners were sitting in pairs, the class discussion was not structured in such a way as to encourage learners to share ideas with their partners about their solution process. Second, in both lessons, much of the teacher talk was procedural questions requiring the learners to produce short procedural answers.

**Discussions and Conclusions from Research**

Given that there was a highly significant difference between the post-test scores in the experimental group and those of the control group, and that the experimental group showed a statistically significant higher gains from pre-test to post-test, it can be concluded that the improvement of the performance in mathematics from pre-test to post-test was not due to chance than due to the fact of having improved the English language proficiency of learners. On the other hand, it can be deduced from the data that even though the English language proficiency level of learners was improved, such improvement had no effect on classroom interaction during the mathematics lessons. When one considers these results from the qualitative and quantitative analyses of data, one is tempted to conclude that the two provide conflicting results. If what is foregrounded in the development of language proficiency in learners is the
basic interpersonal communicative skills (BICS) and not both BICS and CALP, there is no doubt that learner interaction in the class – an enterprise which demands that learners debate, reason, critique, analyse, evaluate, express and justify their opinions using academic language in the class – would not be improved. Little wonder that learners did not ask questions in the post-intervention class, and the class did not become less procedural (and more conceptual and adaptive) by way of the nature of talk in the post-intervention lesson. This also means that there is no causal relationship between achievement in mathematics and interaction in the mathematics class. Improvement in performance does not automatically lead to improvement in mathematics communication in class.

What other conclusion can be drawn from the above seeming dichotomy between test scores and interaction in the mathematics class? The present research study is an indication of the fact that proficiency in the language of instruction (English) is closely linked to achievement in mathematics. But improving learner proficiency in English, even though necessary, is not sufficient to impact on classroom interaction. In any classroom, the teacher plays a key role in the management of the interaction in the classroom (Edwards & Westgate, 1987). The teacher’s ability, therefore, to draw on learners’ linguistic resources - one of which is structuring questions to allow learners to sufficiently express their thinking - is therefore important.

**Recommendations**

The researcher takes seriously the recommendation by the Centre for Development Enterprise that all mathematics (and Science) activities be “closed linked with improved language [English] education” (CDE, 2004: 33-34). But any attempt to improve the language proficiency of learners with the aim of improving academic proficiency should be done in such a way as to develop concurrently, both the Basic interpersonal communicative skills (BICS) and the cognitive-academic language proficiency (CALP), as Cummins would argue. By so doing, there would be a high possibility of learners’ improvement in mathematics learning in English as well as a greater classroom interaction.

Also, appropriate mathematics teacher training (in mathematics) must be accompanied by appropriate training of the teachers in effective English communication (Howie, 2002) and teacher development in strategies of tapping into learners’ linguistic resources.

Why was there a statistically significant difference in achievement between boys and girls from the pre-test and post-test results? Was the language proficiency level of girls greatly improved compared to that of boys? What could have been responsible for the difference? Are the comprehension stories, for example, used in the ASTRALAB ILS gender biased? This could be an important area of research for future study as it could provide invaluable information for education software developers.
Limitations of this Study

Akin to the limitation by way of the number of learners involved in the study is the limitation by way of the duration of the implementation phase. Baker (1993) argues that it takes 5 to 7 years to acquire cognitive-academic language proficiency (CALP) in a second language. Therefore, a more prolonged intervention using the ASTRALAB software would have been worthwhile.

References


Pirie, S. (1998). Crossing the gulf between thought and symbol: Language as (slippery) stepping-stones. In, H. Steinbring; B. Bussi; & A. Sierpienska; (eds.) Language and Communication in the Mathematics Classroom. NCTM, Reston: Virginia. 7-29


