CHAPTER 5

READING SKILL AND LEARNING MATHEMATICS[1]

5.1 Introduction

Increased interaction with Mathematics Access Module students from 1999 had raised some concerns regarding the extent to which low levels of English language proficiency and inadequate reading skills seemed to be undermining students' potential to assimilate information, particularly since they were dealing mainly with text-based study material.

One of the sets of action research cycles described in this thesis was thus associated with a joint project between the Departments of Mathematics and Linguistics, in which reading and its relationship with learning mathematics was investigated. The project (from 2000 to 2003) was divided into a testing and an exploratory phase (Phase I), and two intervention phases (Phases II and III). Each of these phases resulted in a new cycle in the action research process.

In this chapter we now briefly discuss some theoretical aspects of language proficiency, oral and written language and reading proficiency, particularly in English (the language of instruction). A consideration of these factors in relation to students' performance in the Mathematics Access Module examinations gave rise to three specific research questions. Firstly, is there a relationship between reading ability and academic performance in mathematics? Secondly, what specific aspects of reading relate to the reading of mathematics texts? Thirdly, can explicit attention to these reading difficulties play a role in improving performance in mathematics? These questions were the focus of Phases I, II and III of a reading intervention programme for Mathematics Access Module students.

In this chapter we consider the link between mathematics discourse and reading; we review the theoretical background of reading comprehension, focusing in particular on aspects of vocabulary, anaphoric resolution, logical relations, the importance of sequencing, and the interpretation of visually presented information. The methodology for Phases I and II is outlined. Phase I involved the creation and administration of a reading test and the analysis of the results,

[1] This chapter contains material that appears in two articles by Bohlmann and Pretorius, namely 'Reading skills and mathematics', and 'A reading intervention programme for mathematics students'. Copies of these articles are included in Appendix D (Bohlmann & Pretorius, 2002; Bohlmann & Pretorius, 2003).

which tentatively answered the first two research questions. This led to Phase II, which involved the development of a face-to-face intervention programme in an attempt to answer the third question. The results of Phase I and Phase II are then discussed. The need to expand the intervention further led to Phase III, which is described in Chapter 6.

5.2 Language and meaning

We construct meaning and make sense of our world largely through language, and it is thus necessary that we also take into account the verbal skills of students studying mathematics. Poorly developed language skills undermine students' mathematical performance (see for example Bartolini Bussi, 1998: Clark, 1998; Sierpinska, 1998, Ellerton et al., 2000). In the Papua New Guinea Indigenous Mathematics Project (Souviney, 1981), it was reported that English language competence (the language of instruction in that instance) exhibited the strongest relationship with mathematics achievement. There also seemed to be a relationship between early language acquisition and future mathematical ability (Ellerton & Clements, 1988).

Many additional difficulties arise when a student's primary language is an oral rather than a written language. The establishment of the printing press resulted in an 'information explosion', which necessitated classification schemes, hierarchies, relationships and order (Garaway, 1994). In an oral tradition these structures are largely invisible. Vygotsky (1978) proposed that even a minimal level of writing requires a high level of abstraction, and Zepp (1989) considered whether written language could thus be considered a major factor in conceptualisation.

All South African students are required to learn a language other than their mother tongue at school. This has a potential advantage, since the relationship between bilingualism and the ability to learn mathematics is well established. Competence in a language different from the language of instruction has been shown to be a potential advantage, likely to assist in mathematics learning (see for example Duran, 1988; Secada, 1988, Clarkson, 1991). Duran (1988) found that for adult Hispanic bilinguals there appeared to be a relationship between the degree of bilingualism and logical reasoning ability. Several studies of bilingual learners (for example Bain & Yu, 1980; Hakuta & Diaz, 1984) showed cognitive benefits associated with bilingualism. However, these studies reflect a certain degree of mastery of more than one language. Dawe (1983) noted that demonstration of mathematical reasoning ability correlated more highly with first language ability than with second language ability. This suggests that under-development of a student's first language hinders not only the development of the second language, but also the development of other skills (such as mathematics) that may need to be learnt in the second language. These factors have particular significance for many L2 students.

In a review of several studies Secada (1992) found that language proficiency did not completely explain mathematical achievement, and it appeared necessary to investigate the extent to which *reading ability* influenced students' ability to comprehend and do mathematics. Dale & Cuevas (1987) pointed out that proficiency in the language in which mathematics is taught, especially reading proficiency, was a prerequisite for mathematics achievement. Language proficiency and reading are related, but they are conceptually and cognitively different skills that develop in distinct ways. In Chapter 2 we noted the point made by Freitag (1997), that underdeveloped reading skills could limit mathematical development and progress. The pedagogical implications of issues such as these led to the decision to focus on teaching aspects of reading in the context of mathematics, in addition to the mathematical aspects of the Access Module.

Many Mathematics Access Module students appeared to be experiencing problems as a result of their limited English language proficiency and ability to read English, particularly since the study material is provided only in English. In the context of this research the description 'weak readers' usually refers to weak readers in English; however it is increasingly evident that many South African school children with poor English reading skills are also poor readers in their mother tongue, so that reading *per se*, and not only reading in English, appears to be a problem. Pretorius & Machet (2004) found poorly developed reading skills among Zulu school children; in a different study (Matjila & Pretorius, in process) found that secondary school children's comprehension was no better when they read in Setswana than when they read the same text in English, and was in fact at times worse. Similar findings occurred in a project investigating reading skills in Tsonga and English (Pretorius, 2002). Smyth (2002) noted that

> Research conducted in SA and Zimbabwe points to the fact that, for the majority of school children, academic language proficiency [in which the author included reading] in their home language is not sufficiently well established for them to be able to transfer ideas to another language except at the most mundane level. Once these learners are forced to learn through a language which is not their home language, their concept and language development suffers in many ways. This is exacerbated by factors such as the dominance of the transmission mode of teaching and social and affective factors such as low self-esteem in learners and the low status of their home languages (p.109).

Findings such as these also suggest that attempts to provide the study material in the indigenous languages may not be successful, and that students' reading skills cannot be ignored. Earlier in this thesis (see 3.4.1, in Chapter 3) it was noted that the use of English as the language of instruction was not negotiable; further reason for taking English reading skills into account.

As was mentioned in Chapter 2, mathematics is a conceptually complex discipline, in which problem solving is an inherent component. Problems cannot be solved unless the concepts involved are first read, assimilated, and interpreted; strategies for solving problems are also dependent on prior reading, interpretation and application of similar skills in similar or different contexts. Since the reading abilities of Access Module students had increasingly been called into question, a decision was taken to examine their reading skills more closely. Two factors in particular led to this decision. Firstly, there were large numbers of students who were unable to obtain examination admission[2], and those who managed to qualify to write the examination performed poorly. Were their reading skills undermining their ability to cope with the volume of work, and to process text effectively? Secondly, students' limited language proficiency at the productive level (such as writing) had led to the suspicion that such problems possibly stemmed from limited proficiency at the receptive level (e.g. reading).

At this juncture it is important to note the degree of emphasis placed on different aspects of educational practice in different educational settings. Are all the issues that are relevant to contact-teaching environments equally applicable to distance education, and vice versa? Do both contexts suggest the necessity of undertaking research into reading skills? The kind of reading, and the extent to which reading is required, differ in the two educational settings. Furthermore, the discipline in which reading is undertaken also significantly influences both the kind of reading required, and the extent to which reading is necessary. Mathematical reasoning and skill are best developed through interaction. When students encounter mathematical concepts, the mental concepts they form are not necessarily what the study material purports to impart, or what the lecturer intends (see Mason, 2002). At UNISA student access to technological resources cannot be taken for granted, and distance limits the extent to which person-to-person interaction takes place. In mathematics a great deal of information is imparted in contact sessions by unquantifiable and immeasurable techniques such as the tone of voice (for example 'up' accompanied by a higher pitch and an upward gesture), or body language (for example 'lateral

[2] From Chapter 4 it is evident that not all registered students qualified to write the examination. This is discussed in Chapter 8 (see 8.2.2).

surface area' of an object, accompanied by showing the object and touching relevant sides in turn). Print-based distance education in particular focuses on the text as the primary source of information, and well-honed reading skills are essential if the text is to be adequately processed. The research discussed in this chapter and in Chapter 6 thus has particular relevance for distance education, although it may also be applicable to face-to-face teaching.

5.3 Mathematics discourse and reading

There are several prerequisites for any learning, among them the following (Laurillard, 1993). Students need to apprehend the structure of the particular discourse, they need to integrate the sign with the signified, they must relate knowledge to real-life experience, they need to make use of feedback, and they need to reflect on the goal-action-feedback cycle.

In the study of mathematics students are exposed to academic discourse and mathematical discourse. Mathematical discourse includes the symbolic nature of mathematics notation, which demands that students understand what specific symbols represent and what these representations mean. Students need to translate everyday situations into a mathematical context, using the discourse of mathematics, and vice versa. In distance education in particular the role of feedback is critical, particularly in respect of the way students comprehend and apply the feedback they are given. In the absence of sufficiently well developed reading skills, none of the five prerequisites listed above are met.

The BICS/CALP[3] distinction plays an important role in text comprehension. Cummins (1981) postulated the existence of a minimal level of linguistic competence that students must attain in order to perform cognitively demanding tasks. Dawe (1983) further postulated the need for a threshold level of proficiency in what he called CAMP: Cognitive Academic Mathematics Proficiency. Dawe contended that the underlying proficiency that is needed to complete mathematical tasks involves cognitive knowledge (mathematical concepts and their application) embedded in a language specifically structured to express that knowledge. Research has shown that although L2 students may acquire BICS fairly quickly, the acquisition of academic language skills takes an average of five years (see for example Garaway, 1994).

Teaching and understanding mathematics requires familiarity with and understanding of the mathematics register (see for example Dale & Cuevas, 1987; Frawley, 1992). The following

[3] BICS: Basic interpersonal communication skill CALP: Cognitive academic language proficiency

aspects of mathematics discourse have already been discussed in Chapter 2 (see 2.3.2). The mathematics register is abstract, non-redundant and conceptually dense (Prins, 1997). Mathematics texts feature more complex and more compact relationships than normal discourse (Crandall et al., 1980). Parts of mathematics texts are procedural, while other parts aim to develop conceptual knowledge. Mathematics texts are hierarchical and cumulative, and integration of information within and across topics is required in order to derive meaning from what has been read. A mathematics reader thus needs to interact with the text, be alert and attentive, be sensitive to comprehension failure as soon as it happens, and know what to do when comprehension is impaired.

Mathematics discourse is characterised by precision, conciseness and lack of ambiguity. Students need to develop the ability to move comfortably between everyday language and mathematical discourse, with its specialised notation, symbols and terminology. Mathematical symbols and graphic aspects, such as charts and tables, increase conceptual density, and the way they are incorporated can increase or decrease cognitive load. The translations that are required, from everyday language into symbolic and other forms, create the situation in which the 'language of mathematics' is at times a whole new language. Many students would agree with Pirie's version of Goethe's comment: 'Mathematicians are like the French; if you talk to them, they translate it into their own language, and instantly it becomes something quite different' (Pirie, 1998, p. 7).

While these issues may also arise in other disciplines they are particularly relevant in mathematics, where the cumulative and hierarchical nature of mathematical concepts plays a significant role.

5.4 Reading comprehension: theoretical background

In Chapter 4 the theoretical framework largely related to mathematics. In this chapter there is a shift to the theoretical framework of a different discipline, namely linguistics. It is interesting to note that mathematicians are becoming increasingly aware of the relevance of theoretical aspects of disciplines such as linguistics with respect to students' comprehension of mathematics (see for example Mason, 2002).

Reading is more than fluency in articulating what is written. In the context of this study, reading refers to *the construction of meaning* and not *decoding* (i.e. attributing meaning to combinations of letters). The interaction between decoding and comprehension in skilled readers happens rapidly and simultaneously. Comprehension cannot effectively occur until decoding skills have been mastered (e.g. Perfetti, 1988). However, skill in decoding does not necessarily imply skill in comprehension. Many readers may readily decode text but still have difficulty understanding what has just been decoded (Daneman, 1991; Yuill & Oakhill, 1991).

Readers construct meaning while they read by building up a coherent mental representation of the text. This representation is a mental map of what the text is about. It is constructed from explicit information in the text and from the inferencing and integrative processes that readers engage in to link up items of information in the text to one another, and to items of information stored in long-term memory. If readers cannot create a coherent representation of what the text is about, then meaningful comprehension does not occur.

In order to assess the extent to which readers are constructing meaning as they read, it is important to examine whether they do in fact perceive the links between items of information in the text. Some of the linking processes that contribute to meaning construction during reading were thus investigated more closely.

5.4.1 Anaphoric resolution

Anaphora basically involves repeated reference in discourse. A referent relating to an item that is introduced into a discourse is referred to again, either by repeating the same linguistic item (e.g. noun or proper noun) or by means of another linguistic item (e.g. pronoun or synonym). Consider, for example, the repeated reference in the following mathematics text:

> Multiplication is denoted by the symbols x, **.** or ( ). The result of multiplying two numbers *a* and *b* is called the product of *a* and *b*, and we usually write *a* x *b* or *a.b*. Because *a* and *b* represent two different numbers (and are not two digits that make up a single number) there is no confusion if we write *ab* instead of *a* x *b*. It is easy to see that we cannot do <u>this</u> when numerals are used, because 23 does not mean 2 x 3 (Book 2, p. 54)

The highlighted phrase mentions a specific convention in the text, and it is referred to again by means of the determiner *this*. In the example above, the word ‘this’ is understood in relation to the conditional clause referring to the notion of writing *ab* instead of *a* x *b*. The underlined item in the text is called an anaphor, and the shaded entity it refers back to is called the referent. Successful anaphoric resolution contributes to the construction of coherent text representation because it enables the reader to identify and track topic continuity and shifts in the topic, and to make connections between elements in the discourse. Skilled readers should be able to resolve anaphors with almost total accuracy (Webber, 1980).

5.4.2 Logical relations

There are many different types of conceptual relations (i.e. ways in which different concepts in text are related to one another). Coherence in a text derives to a large extent from such underlying relations. In mathematics the so-called logical relations are of particular significance. These relations include four basic types, viz. additive (X *and* Y), temporal (X *then* Y), causal (X, *as a result* Y*)* and contrastive relations (X. *However,*Y).

Research findings indicate that knowledge of such relations distinguishes skilled from less skilled readers (e.g. Meyer et al., 1980; Geva & Ryan, 1985). Perception of these relations is fundamental to the construction of coherent mental representations of text. Skilled readers perceive these relations almost unconsciously. In the South African context the problem of poor construction of mental representation is exacerbated by the fact that several African languages make little use of logical connectors (Clarkson, 1991; Rutherford, 1993). If logical connectors such as 'and', 'but', 'since' or 'however' are overlooked or misunderstood it is unlikely that students will make appropriate links between items of information in the text.

In this study, attention was specifically focused on causal and contrastive relations since they are a common feature of mathematics discourse.

Causal and conditional causal relations

The concept of causality refers to the relationship between two events, such that the first one, the antecedent X, brings about the second, the consequent Y. Although there are many different types of causal relations (Pretorius, 1994), in this study causal relations were broadly divided into two categories, namely *general causal relations* and *conditional causal relations*.

The first category includes relations where the antecedent causes the consequent, or comprises a premise or reason for a consequent result. For example, the concept expressed in a prior unit of text provides a basis from which a conclusion is drawn. The supporting statement(s) X can comprise an observation, argument, or evidence, from which a deduction Y is drawn, as we see from the following extended causal argument. The causal conjunctives are given in italics.

Consider the logarithmic function $y = f(x) = \log_a x$. We know that $D_f = \{x: x > 0\}$. *Thus* for the function g defined by $g(x) = \log_a(2x + 1)$, we have $D_g = \{x: x > -½\}$. *Hence* $x = -1$ is not an element of D_g.

The second category includes a specific type of causality involving *conditional causal* clauses. This distinction is made because of the high frequency of *if - then* clauses in mathematical texts. Conditional clauses describe a situation in which it is claimed that something is the case, or will take place, provided that some other situation exists or comes about. This kind of logical relation is regarded as a subcategory of the causal relation since there is a dependency relation between the X and Y members, such that Y does not occur unless X occurs. Consider the example below.

If $x = 2$, then $x^2 + 1 = 5$.

Cause: $x = 2$ Result: $x^2 + 1 = 5$

Research has established that the recognition of causally linked elements in a text is an important determinant of text comprehension (see for example Trabasso et al., 1989).

Contrastive relations

Another important category of logical relations is that of contrastive relations. In a contrastive relation, the second statement in the ‘pair’ carries information that counters the information in the first part. It presents an opposing or unexpected point of view to what has been stated. Skilled reading naturally includes the ability to perceive such aspects of the text. To understand contrastives, it is necessary to understand the line of argument presented in the first pair part in order to recognise that the second pair part reflects an opposing, contrasting or qualifying point of view. For example:

When we work with natural numbers we find that adding two natural numbers results in a natural number *but* subtracting one natural number from another does not necessarily result in a natural number. For example, $3 + 5 = 8$, and 3, 5 and 8 are all natural numbers. *However,* $8 - 5 = 3$ and $3 \in \mathbb{N}$, *but* $5 - 8$ is a calculation that cannot be performed in $\mathbb{N}$ (Book 2, p.70).

In the above example, the argument concerns the additive operation involving natural numbers, which is then qualified. The view that follows (signalled in italics by *however* and later by *but*) is a contrastive one in the sense that it qualifies the previous phrase by pointing out that subtraction of two natural numbers does not necessarily result in a natural number.

5.4.3 Sequencing

Sequencing refers to the way in which propositions in a text follow one another. The most obvious type of sequencing is temporal sequencing, where sentences in a discourse are linked by means of a temporal sequence. Temporal sequences are also often tied up with causal relations, since many states/events/arguments are the result of prior causes or reasons and follow them temporally (although their actual order of presentation in a text may be reversed).

In mathematical texts concepts and arguments are often presented within a developmental or logical perspective. A reader needs to keep track of sequence in order to understand the relationships between successive propositions. The ability to sequence ideas is an important reasoning skill, which can affect performance in a number of academic areas (Lesiak & Bradley-Johnson, 1983).

5.4.4 Visually presented information

Verbal information is often represented and complemented by graphics (tables, graphs, schemas and other visual devices), which form an integral part of mathematics texts. The ability to read visually presented information and to relate it to the verbal information forms a crucial part of reading mathematics. Functional literacy assumes the ability to read and understand statistical graphs and tables (Friel et al., 2001). While this study relates to statistical graphs in particular, it is clearly relevant to other graphs as well. Students in general appear to have difficulty with information presented graphically, for

> cognitive reasons related to the specific characteristics of the language of graphs and epistemological reasons related to the beliefs about the nature of mathematics and the status of graphic representations in mathematics (Kaldrimidou & Ikonomou, 1998, p. 272).

For example, students lacking exposure to graphic devices consider them as decorations rather than as a central part of the text (Rutherford, 1993). Furthermore, in translations between graphs and the situations they represent, two major difficulties that students appear to experience involve confusion between the meaning of slope and height, and iconic interpretation (i.e. the meanings and purpose of different icons used in various graphical representations of information) (Roth & Bowen, 2001). It cannot be assumed that students can correctly interpret graphs without first learning how to ‘read’ them.

5.4.5 Vocabulary

There are differences in the distribution of words that occur in oral and written contexts.-A distinction can be made between three main categories[4] of words, viz. *common* or *high frequency* words, *academic* words and *technical* words. *High frequency* words occur predominantly in everyday oral contexts (BICS) and comprise a core of about 5 000 to 6 000 common words. The rest of the English vocabulary (a much larger group) comprises *low frequency* words. *Academic words* refer to a group of about 800 - 1 000 low frequency words that seldom occur in everyday conversation but occur commonly in academic discourse, e.g. words such as *hypothesis*, *proponent*, *assumption*, or *paradigm*. These words support CALP and occur across discipline boundaries. The final group of low frequency words, namely *technical* words, comprises discipline-related words that occur with high frequency in a specific discipline but are seldom used outside of the discipline. Technical terms in mathematics include *integer, logarithm, square root, exponent,* etc. In addition mathematics borrows terminology from everyday life, such as *function*, but uses these words in a unique way. Rutherford (1993) refers to words such as these as 'portmanteau' words, using Lewis Carroll's analogy to describe the situation in which more then one meaning is packed up into a single word.

Knowledge of low frequency words appears to be associated with academic success. Nation (see Nation & Newton, 1997) argues that about 87% of academic texts are covered by the 2 000 high frequency word families, while the 800 academic words from the University Word List (UWL) cover an additional 8% of text. The balance of words is covered by discipline-specific or uncommon low frequency words. In spite of the low percentage of text covered by academic words, knowledge of these words is associated with academic performance. Because most new words from puberty onwards are acquired through exposure to written texts rather than from oral discourse, an assessment of vocabulary levels provides an indirect index of a student's reading level. In international assessment practice academic vocabulary development is regarded as one of the more reliable determiners of academic success (Cooper, 1996). Students who do little reading have limited exposure to low frequency words. From the few vocabulary studies that have been undertaken in South Africa, we find that L2 students who study through the medium of English have inadequate vocabulary levels, particularly of low frequency words. Cooper (1996)

[4] The research carried out in 1995 by Nation & Hwang (1997) suggests a base list of 2 000 high frequency word families in English. The University Word List (UWL) contains the most frequent words that occur in academic texts across disciplines (Xue & Nation, 1984).

found a relationship between vocabulary levels and academic performance, with weak students having significantly fewer low frequency words.

Vocabulary knowledge is a good predictor of reading comprehension. Although this makes sense, since words form the building blocks of meaning, it does not explain why vocabulary differences arise in the first place. How do skilled readers come to acquire so many more words than their unskilled counterparts? Daneman argues that differences in vocabulary size are ‘the *result* of differences in reading skill rather than the primary cause of such differences’ (Daneman, 1991, p. 525). In other words, students’ scores on a vocabulary test containing both high and low frequency words can indirectly indicate the extent to which they are ‘readers’.

5.5 Methodology

This section describes the subjects involved, the materials used and the procedures undertaken during the different action research cycles involved. Phase I of the reading intervention (in 2000) involved the creation of reading tests. Analysis of the results led to the development of a face-to-face intervention programme which was implemented in 2001 (Phase II). This intervention was modified and led to a third phase, namely a large-scale intervention (Phase III), which will be discussed in the following chapter.

5.5.1 Creation of reading test (Phase I)

In order to build an in-depth profile of the students’ reading ability, a series of tests was designed that focused on specific reading skills. Authentic mathematics texts taken from the Mathematics Access Module study guides were used. The tests were first piloted on a small group (25) of volunteer Access Module students. The purpose of the pilot tests was to identify potential problems with the selected texts and the test items. The alpha (Cronbach) model reliability test was applied to each component of the test. Sections B, C and D of the final test (described below) had acceptable alpha reliability coefficients (0,85, 0,70 and 0,80, respectively). Once the test had been refined, it was sent to all Access Module students (960, of whom 402 responded) in 2000. It then became the pretest that was used in the face-to-face intervention programme in 2001.

5.5.2 The face-to-face intervention programme (Phase II)

Purpose

The purpose of this phase was to set up a reading intervention programme on a voluntary basis for students enrolled in the Mathematics Access Module, to determine whether explicit attention given to reading would help them understand their mathematics study guides better. The programme entailed 22 weekly two-hour contact sessions from March to August 2001[5]. Attendance was open to all on-campus students enrolled for the module. Between 50 and 60 students initially showed interest. Attendance fluctuated but after about the fifth week remained more or less constant, and 33 students participated in the entire programme.

In order to test the efficacy of the reading programme and to monitor the students' progress, pre- and posttests were administered, in March and August, respectively. The inherent disadvantage of 'mechanistic' pre- and posttests was recognised, namely that they are intended to prove that an innovation works (or does not) but instead often 'promote conditions that minimize the chances of success by measuring progress in terms of deficiencies with respect to simplistic conceptions of success' (English et al., 2002, p. 801). However, the end appeared to justify the means in that the tests did yield useful information and did not appear to impact negatively on the students, possibly because the reasons for the administration of all tests were clearly explained to all participants.

Initial testing

Initial testing dealt with aspects of reading and attitudes to mathematics and included an attempt to gauge the way in which students approached solving a simple quantitative problem. A *Maths Profile* and a *Maths Questionnaire* (administered in Week 3, both taking roughly five minutes each) probed students' perceptions regarding their own mathematical ability, and their mathematical background. It was the intention that the *Profile* would be given back to students in September, so that they could respond to another set of open-ended questions about their feelings and attitudes to learning mathematics at the end of the intervention. Students participated in a quiz, called the *March Maths Quiz* in Week 4. Students were given 15 minutes for the activity, which consisted of two questions which were linguistically and cognitively undemanding, and contextually unsupported.

The *reading pretest* was administered in Week 2. Students could take as much time as they needed. It comprised the following four sections, namely Sections A, B C and D.

[5] The intended weekly activities were set out in a table for students. It was discussed during the first session of the intervention programme.

Section A consisted of a questionnaire to obtain biographical information, such as matriculation performance. The questionnaire also probed students' attitudes towards reading, perceptions of their own reading skills, and obtained information concerning their reading practices.

Although reading is fundamentally a cognitive-linguistic activity, reading practices are embedded within a socio-cultural context. Reading attitudes and values affect, and are affected by, home, school, work and community literacy practices, as well as the levels of literacy that students attain. Any discussion of the reading situation in South Africa should therefore also be situated within the broader context of culture and environment. It was thus important to obtain some biographical information.

Section B assessed student understanding of anaphoric references. It comprised 21 paragraphs of mathematics texts, and tested 26 anaphoric items.

Section C tested student vocabulary development by using mathematical text. It comprised 15 multiple-choice items, testing a mixture of high frequency, academic and technical terms.

Section D comprised 56 items, testing the comprehension of logical relations, the sequencing of ideas and the interpretation of visually presented information. Items that tested the readers' ability to infer sequencing consisted of the re-ordering of scrambled paragraphs. This method of testing comprehension has been shown to have high psychometric value (Pagé, 1990).

In Week 2 r*eading rates* were assessed, and this aspect of the test also included a *comprehension test*, to prevent mindless skimming. Students were first asked to read a given passage carefully (well enough to be able to answer questions). The passage was adapted from an article entitled 'The impact of Dogon religious beliefs on their concept of numbers' (King, 1997). After one minute students were told to stop reading and indicate in the text where they had stopped. They could then continue reading, and answer the comprehension questions. Their scripts were later handed in and the number of words they had read up to the marked spot was counted. It was then possible to calculate the reading rate (words per minute) for each student. Distance learning requires students to assimilate a considerable amount of material, and the rate at which they read is critical. Skilled L1 readers typically read leisure texts at about 350 words per minute (wpm), but may slow down to 200 wpm for more complex texts. It is suggested (e.g. Anderson, 1999) that L2 students should read at approximately 60% of the rate of L1 readers. The reading rate for study purposes will be slower than the normal reading rate (Rowntree, 1990), especially in mathematics, where the conceptual density of the discourse and the interpretative demands made by mathematical symbols and by graphic devices impose additional demands.

Interviews

In order to obtain more in-depth data on the students and to complement the more formal quantitative tests with additional qualitative information, one of the lecturers[6] conducted one-hour *personal interviews* with each student. All 33 students were interviewed over a period of several weeks, and notes were kept, but the interviews were not recorded in any other way. Students read aloud a passage of narrative text (Dangarembga, 1988) and a passage from one of their mathematics study guides, dealing with exponential growth. Their reading fluency and decoding skills were assessed in the two different contexts. The students were asked about their reading habits and their attitudes towards reading; they were also given a hands-on demonstration of how to search for a book on the UNISA Library computer system.

The components of the programme

Team members in the Departments of Mathematics and Linguistics jointly designed the intervention programme. The emphasis was on reading in general and the reading of mathematics texts in particular. The following activities were undertaken.

Extensive reading activities

There is strong evidence from research that pleasure reading (i.e. reading fiction and non-fiction for pleasure and not for study purposes) not only improves reading skill but also expands vocabulary development, increases general knowledge and conceptual development, improves syntactic knowledge and deepens readers' awareness of text structure and the conventions of written language (e.g. Hafiz & Tudor, 1989; Krashen, 1993; Mason & Krashen, 1997). The extensive reading component of the programme (the first half hour of each two hour session) thus involved encouraging the students to spend more time reading for pleasure. A steady supply of popular magazines and paperback novels was maintained, and the following extensive reading activities were undertaken.

[6] Dr E J Pretorius

The students were expected to read a magazine article every week. Students completed 'magazine report' forms. These reports were handed in each week, marked by one of the lecturers and handed back to the students in the next session.

The students were encouraged to read one book each month. 'Book report' forms were completed, marked and handed back. Students were encouraged to join a local community library, and reminded to use the UNISA Library 'book search' facilities.

The students were encouraged to take responsibility for their vocabulary development and to actively expand their word knowledge by using a personal 'mini-dictionary' and interacting with a 'word buddy'.

Intensive reading activities

Reading skill improves through practice. So too in mathematics, 'immersion' in the language of mathematics is seen to have value in acquiring mathematical reading skills (Krussel & Dick, 1998). The remaining one and a half hours of each weekly session focused on developing an awareness of what it means to 'read mathematics'. Intensive reading activities focused on the following specific reading skills and strategies, and applied them to mathematics texts.

<u>'Reading' mathematics</u>

The results of the 'Maths Quiz' promoted a discussion of effective reading strategies for mathematics, such as that described by Siegel and Fonzi (1995) as **PQ4R**, where the acronym represents the following activities:

P	**Preview**, i.e. know in advance what the text is about
Q	**Question**, i.e. phrase questions about the content while reading
4R	**Read**, i.e. interact with the text, be attentive to textual clues
	Reflect, i.e. more detailed reading; re-reading
	Rewrite, i.e. 'translate' language statements to mathematics statements (e.g. representing language statements using appropriate symbols and notation), provide contextual support if necessary (e.g. set up tables or draw diagrams)
	Review, i.e. check for consistency, correct units, completeness, logic.

Macro and microstructure of text

The macro structure of texts was explained, including the general organisation of textbooks (e.g. the purpose of title page, index, table of contents, etc.). Students were shown the importance of using previewing strategies to create a framework for learning; they learnt how to create a schema of a topic as a way of identifying beforehand what the topic was about, and how different components of the topic were related.

Students were also shown the importance of the microstructure of text. They were made aware of the tendency to read passively, without responding appropriately to different textual demands, such as passages providing information, or requiring a response to an instruction or a question. Different types of reading (i.e. skimming, scanning, study reading) were also discussed.

Vocabulary

Attention was given to developing vocabulary, focusing on low frequency words, namely academic or technical (mainly mathematical) words. Techniques for finding the meanings of unfamiliar words were discussed and practised. Problems caused by borrowed terminology were also discussed.

Students also learnt about relationships between pairs of words (e.g. synonyms, antonyms and word families), and about the importance of prepositions.

Logical relations

Logical relations were discussed, and students were given practice in reading such relations. Examples from the study guides were used to highlight the importance of logical relations in mathematics texts.

The notion of causality was explained, and words that signal causal relations, such as *thus*, *therefore*, were identified. Conditional causal relations, in which an outcome is dependent on a particular condition, are particularly important in mathematics, where they are often signaled by the words *if …then*. Uni-directional and bi-directional conditional causal relations were discussed, as the distinction between these is also important in mathematics. More abstract causal relations, in which the signaling words are implicit rather than explicit, were considered as well.

Students were also made aware of the linguistic order of a causal relation (i.e. although in the real world the cause always precedes the effect, linguistic expressions of causal relations often state the effect before the cause). Causal chains (i.e. multiple causal relations), in which the result that follows from a particular reason itself becomes the reason for a subsequent result, are a common feature of mathematics, and were also discussed.

The notion of contrastive arguments was also dealt with, and words signaling contrastive relations, such as *but*, *however*, were discussed.

Anaphoric references

Weaker readers generally ignore anaphors and have little awareness of their importance in constructing meaning when they read. The way in which items in a text are linked by means of anaphoric devices was explained. Extracts from magazines and newspapers and passages from the mathematics study guides showed the students how anaphors are used.

Interpreting and using tables and graphs

Attention was given to 'reading' tables and graphs. The terminology of tables, such as *row*, *column*, *cell*, was discussed. Emphasis was placed on the need for careful reading to identify concepts of ordinality (e.g. the intersection of the *second* row and the *fourth* column), cardinality (e.g. *once*, *twice*) and orientation (e.g. *diagonal*, *middle*, *horizontal*). Prepositions such as *above*, *below*, *across* often occur in contexts such as these and are critical in correctly interpreting tables and graphs. These common English words are often overlooked and students thus miss the nuances of meaning in descriptions such as approaching *from* the left, moving *to* the left, *above* the line, *on* the line, *between* two points.

These concepts were also discussed in relation to the Cartesian plane. Students experience particular difficulty in, for example, the notion that on the graph of some function, a point above the x-axis but to the left of the y-axis is associated with a positive function value, even though it has a negative x-coordinate. In situations like these the use of unfamiliar prepositions and words implying orientation, together with the cognitive demands of mathematical concepts, create extremely dense text, which may require considerable concentration and re-reading.

Final Testing

In August the students completed a *questionnaire evaluating* the different sessions. The questionnaire distinguished between general reading activities and specifically mathematical reading activities. Students rated the activities on a scale from 1 (most negative) to 4 (most positive); several open-ended questions yielded additional information.

A *reading posttest* consisted of the same items as those in Sections B, C and D of the pretests. Since the pre- and posttests were several months apart, it was decided that there would be few memory effects carrying over from the first to the second set of tests. A different *reading speed* and *comprehension* test was administered: it was based on a passage from an article dealing with the mathematics of mountain bikes (Laridon & Presmeg, 1998).

An experimental and a control group were set up at the commencement of the intervention. It was arranged that a group of 25 students who attended the Access Module tutorial classes at one of the Learning Centres would serve as the control group. Although these classes involved additional mathematics instruction, they were given no reading instruction. The control group was given the same reading pretest as the intervention group in March 2001. However, the tutor failed to administer the posttest in August 2001. An attempt was made to rectify this situation, and the students were sent copies of the test by mail after their mathematics examination in November 2001 and asked to complete them and return them in prepaid envelopes. Only 5 of the 25 students responded, and it was thus not possible to make meaningful deductions from the small number of responses.

Information summary

The qualitative and quantitative data obtained from students during the intervention phase was recorded using an inventory.

5.6 Results (Phase I)

5.6.1 Relationship between overall reading scores and examination performance

Not all 402 respondents had scores in all categories. For example, some students who completed the reading test did not obtain examination admission[7] or did not write the examination, and thus had no examination mark; not all students completed all sections of the different tests. The final results for this phase reflect the scores of 308 students. The students were categorised into

[7] See Chapter 8 (8.2.2).

different groups, based on their overall reading scores (i.e. the sum of their scores for Sections B, C and D of the reading test, converted to percentages) and their performance in the final mathematics examination[8]. The reading scores suggested four groups of students:

Reading Group 1: Students with comprehension levels of 45% or less, who had major reading comprehension problems.

Reading Group 2: Students with comprehension levels of between 46% and 59%, who were reading at frustration level and had a fragmented understanding of what they read.

Reading Group 3: Students with comprehension levels of between 60% and 74%, who coped to a large extent but would have benefited from reading instruction.

Reading Group 4: Students who scored 75% or higher, who understood most of what they read.

Table 5.1 shows a clear relationship between examination performance and reading score, indicating that weak reading skills and poor performance go hand in hand. The table also shows that the mean scores in each subcomponent of the test improve as overall reading ability improves.

Table 5.1:

Mean reading comprehension scores (%) for the four reading ability groups

	Reading Group 1 *n* = 45	**Reading Group 2** *n* = 78	**Reading Group 3** *n* = 95	**Reading Group 4** *n* = 90
Section B: Anaphors	28,6	52,5	68,2	80,8
Section C: Vocabulary	45,4	58,4	73,7	80,8
Section D: Logical relations, graphs	37,2	49,4	61,4	78,8
Mathematics examination	24,8	32,5	33,4	41,7

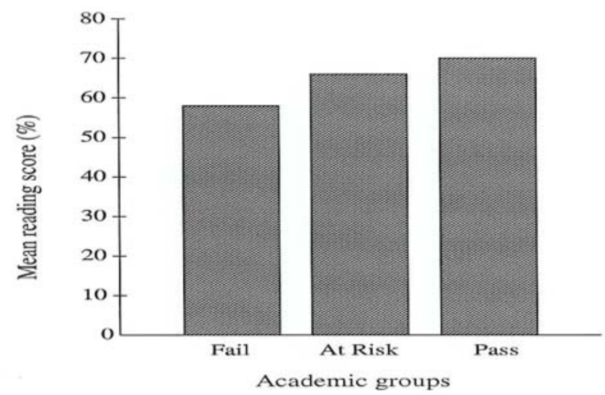
[8] Examination results are given in Chapter 8 (see Table 8.9).

The mathematics examination scores showed that very few students scored between 60% and 70%. The examination performance was poor, with a mean of 34,5% and a mode of 31%. The examination marks suggested the following categories, referred to as academic groups: Fail (0% to 29%), At Risk (30% to 59%), and Pass (60% or above[9]). These labels are arbitrary, but nevertheless useful for the discussion that follows. Table 5.1 and Figure 5.1 summarise the overall results.

Figure 5.1 reflects the mean reading scores in relation to the three academic groups. This bar graph reflects a roughly 10% difference in the reading scores of students who passed their examination with over 60% (students in the 'Pass' category), and the low reading scores of students who obtained below 30% (students in the 'Fail' category).

Figure 5.1:

Mean reading scores for three academic groups



5.6.2 Relationship between reading test components and examination performance

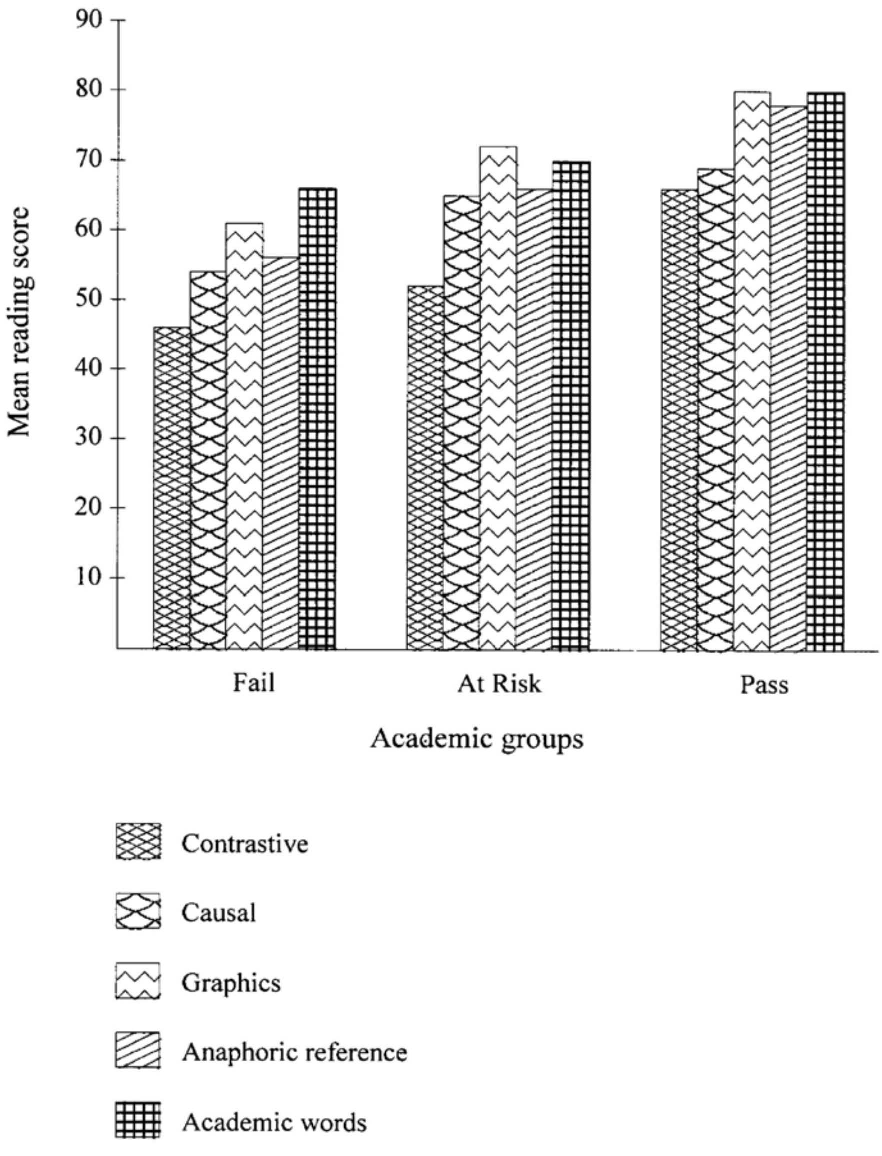
Further statistical analysis was carried out, and additional information was obtained from a one-way analysis of variance (ANOVA) and from a cluster analysis (see Tables 2 and 3 in Bohlmann & Pretorius, 2002). The ANOVA showed consistently significant differences between students in the Fail group and the At Risk group in sections B, C and D of the reading test, and between all

[9] To pass an examination a student must obtain 50% or more. This 'Pass' category intentionally reflects students with marks above the minimum, clearly outside the 'At Risk' category, for the purpose of clustering students, albeit fairly broadly.

groups with respect to sections B and D (i.e. excluding the vocabulary component). The overall scores on all three components also show significant differences between all three academic groups. The cluster analysis showed that in all subcomponents of the reading test there was again a relationship between reading performance and performance in the mathematics examination: students in the Fail group performed most poorly in all components, with results improving across the other two categories. Figure 5.2 reflects these differences.

Figure 5.2:

Performance across categories in different components of reading



The most important result emerging from Phase I was that students with overall reading scores of below 60% were unlikely to pass their mathematics examination. Students who passed had higher reading scores than students who were at risk or who failed. Students whose overall reading scores were below 45% typically failed their mathematics examination hopelessly, while those with scores of 75% or above typically passed their mathematics examination with 60% or more. Students with less than 30% for mathematics were typically students with poor reading skills. These results suggest that the stronger a student's reading ability, the better his/her chances of performing well in the mathematics examination. While high reading scores do not guarantee mathematical success, a low reading score seems to be a barrier to effective mathematical performance.

5.7 Results (Phase II)

In this section we first consider the student characteristics that emerged from the study, then discuss the results of the various tests.

5.7.1 Student characteristics and perceptions

Section A of the pretest showed that the students in the intervention programme had similar profiles to their counterparts in 2000 in that they had low reading levels (in fact, their overall reading levels were lower than the group average in 2000), they did not engage in meaningful reading practices outside the confines of their studies and there were few books and few literacy role models in the home. Most of them regarded themselves as 'average' readers, even though the pretest results indicated otherwise. It also appeared that for many students their past experience of mathematics teaching had not been optimal. They had had limited exposure to 'reading' mathematics, as textbooks were often lacking.

The questionnaire 'My Maths Profile' was not used precisely as intended. The last section asked students to comment on general problems (i.e. not content-specific) they were experiencing regarding studying mathematics in March, at the beginning of the programme, and again in September, at the end. For a variety of reasons the Profiles were not given back to the students in September, and that section was thus not completed. From the two mathematics questionnaires (completed by 49 students) the following problems emerged regarding past teaching. Table 5.2 summarises the information obtained.

Table 5.2:

Previous mathematics teaching

Problem encountered	Number of students
More attention to administrative duties than to mathematics	2
Teacher was discouraging	3
Too many gaps in what was taught	2
Teacher could not be understood	10
Teacher perceived as lazy	3
Few opportunities for regular practice	2
No teacher	2
Basic mathematics building blocks missing	3

However, a large number of the students were positive about the teachers (16) (they were friendly, willing to help, encouraged practice). A few students recognised the extent to which they had been personally responsible for their problems: lack of commitment, unwillingness to practise, assumed they had understood concepts, but later discovered that they had not. One student mentioned that although she knew the answer, she performed poorly: 'because of thinking fast and writing slow I skip other information'.

In response to the following open-ended question (in March): 'In a paragraph, briefly explain how you feel about your maths, and what kinds of problems you have', several categories of problems emerged. They are summarised in Table 5.3.

Table 5.3:

Difficulties experienced by students

Problems encountered	Number of students
Feeling inadequate	9
Wrong approach to studying (e.g. memorisation)	3
Difficulty understanding what was being asked or explained	12
Difficulty handling so-called 'word problems'	6
Difficulty applying or transferring concepts	3
Difficulty with the terminology of mathematics	3

A pervasive lack of confidence and sense of inadequacy is illustrated by one student's comment:

> I love this subject, but I doubt myself that I would ever understand it, because I have a lot of people who can help me, but after being helped when I am alone or writting an exam it seems as if I never came across such an equation. Maybe I have a forgetting problem.

However, there were also those who, in response to a question regarding their *expected* performance in the Mathematics Access Module examination, thought they would pass with flying colours, which proved not to be the case.

In the March Maths Quiz the students performed poorly and showed little evidence of any reading strategies required to understand the problems and answer the questions, such as breaking the text up into smaller sections, drawing a diagram, checking what was actually asked and whether they had answered the question. Only seven of the 49 students who participated in the quiz scored any marks in the first question (one student scored two out of ten; the remaining six scored one out of ten). They fared slightly better in the second question, averaging approximately 35%.

5.7.2 Reading pre- and posttest results

The *pretests* showed that, in general, the students entered the reading programme with low reading levels, with a mean reading score of 46% (see Table 5.4). Their anaphoric resolution was inaccurate and low, they had low vocabulary levels, especially with regard to academic words, and poor understanding of logical relations and visually presented information. They were also reading at well below recommended speeds (average reading speed was 92 wpm), with poor comprehension levels (average 46%). Some of the students were reading at approximately five years below their maturation level. The *posttests* (see Table 5.4) showed marked increases in all aspects of reading that were investigated, apart from vocabulary.

Table 5.4:

Mean reading scores in the pretests (March 2001) and posttests (August 2001)

Reading component	Pretests	Posttests
Section B: Anaphoric references	46%	61%
Section C: Vocabulary	54%	59%
Section D: Text-semantic relations, graphic information	39%	47%
Overall reading comprehension	46%	56%
Reading rate (wpm)	92 wpm	136 wpm

Results in Section A showed that the students had not been exposed to a print-rich environment, and that they did very little reading beyond what was strictly necessary for study purposes. The pretest results indicated that most of the students appeared to be weak readers who read slowly and understood very little of what they read. After the 22-week intervention period, the posttests showed an increase in reading skills (the group mean increased from 46% to 56%). Despite these gains, the majority of students would still be regarded as weak readers, falling into Reading Groups 1 or 2 (see 5.6.1).

Because there were no posttest results from the control group, comparisons between the two groups were not possible.

After the intervention programme the students' reading skills and performance in the mathematics examination[10] were considered in relation to other language variables, as reflected in their **matriculation English** results and their **matriculation first language** results (in this case an African language), and in relation to their performance in the **mathematics assignments**[11] they submitted during the intervention period (reflected as the mean mathematics assignment score). (See Table 5.5.)

Table 5.5:

Comparison of mean scores (%) of students in intervention group

	Outright fail (*n* = 8)	**Admission to supplementary** (*n* = 16)	**Pass** (*n* = 11)
Reading: **Pretest** **Posttest**	30,5 47,0	46,2 52,3	57,7 66,8
Matric English	42,8	43,6	48,1
Matric African language	53,3	57,0	61,6
Mathematics assignments	41,6	50,5	54,8

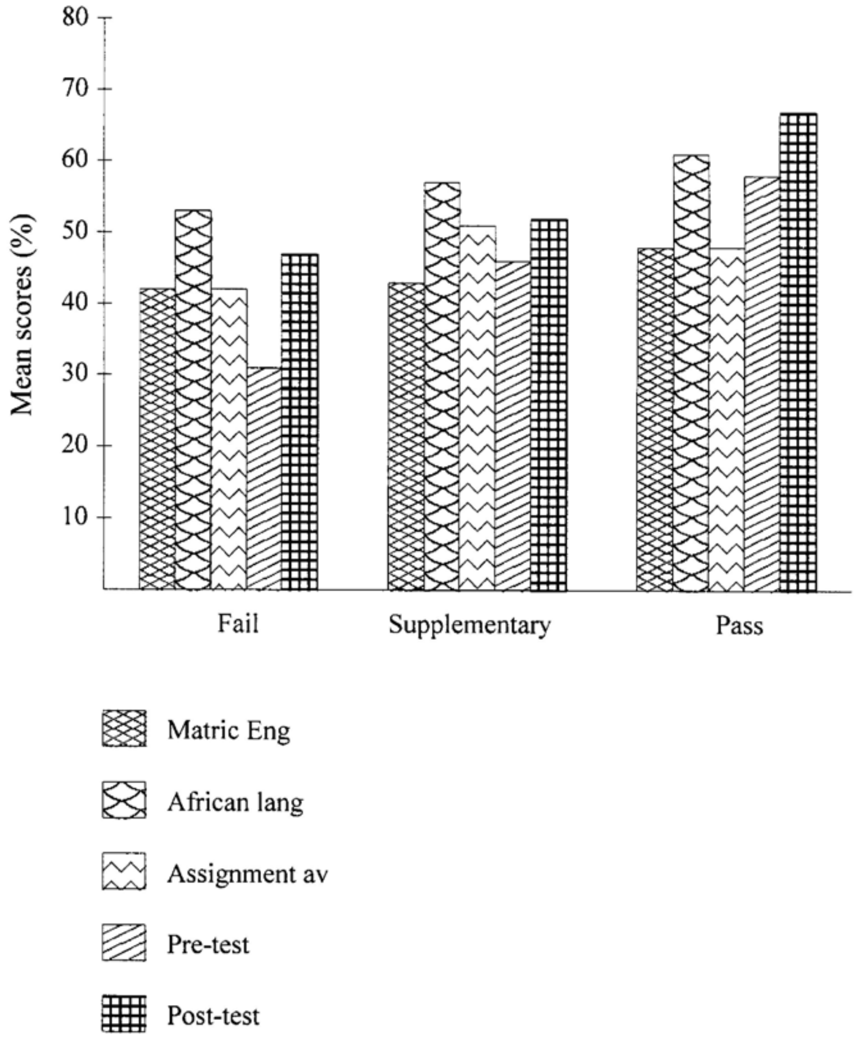
There were 33 students in the intervention group. Of these, 9 passed the examination, 8 failed outright and 16 qualified to write the supplementary examination. Of these, only 2 passed, giving a total of 11 passes and 22 failures. These results were in line with the findings from Phase I,

[10] Examination results are given in Chapter 8 (see Table 8.9).
[11] The matriculation mathematics results were not considered, since several students had not taken mathematics as a matriculation subject.

where it had been predicted that students with reading scores below 60% would fail. Figure 5.3 shows the difference in performance in these variables between the three academic groups (Fail, Admitted to Supplementary, Pass).

Figure 5.3:

Differences in performance in all variables between the three academic groups



Note: It has already been pointed out (see 3.3 in Chapter 3) that two parallel sets of interventions were taking place at this time. The examination results of the students in the face-to-face intervention may thus also have been affected by their involvement in the project assignment (which will be described in Chapter 7). However, given the performance of the students in the project, this seems unlikely. The possible impact of the project on the results of Phase II was not considered.

The Fail group was relatively weaker in all three verbal variables (reading, English and African language) as well as the mathematics variable (mathematics assignments), while the Pass group was relatively stronger in all these aspects. The pass rate of students in the intervention group (33,3%) was higher than the overall pass rate[12] (24,7%), hardly unexpected given the possibly greater level of motivation prevalent in volunteer groups, and the higher degree of academic staff input over the intervention period.

The Kruskal-Wallis test was applied to check for significant differences between these three academic groups for all sets of variables. No significant differences were found between the groups with regard to matriculation English, matriculation African language or mean mathematics assignment score. In contrast, a significant difference was found between the groups in terms of the reading scores:

Pretest scores: $\chi^2 = 11{,}018$; df = 2; $p < 0{,}004$

Posttest scores: $\chi^2 = 7{,}455$; df = 2; $p < 0{,}02$.

Pearson Product Moment correlations (expressed as an *r* score) were then computed to see how these variables related to one another and to the mathematics examination scores. The results in Table 5.6 again suggest a fairly robust relationship between the reading scores and the mathematics examination performance, while there is a weaker or no significant relationship between the other variables and the examination marks. The strongest correlation (pretest reading scores with mathematics examination marks) was highly significant.

[12] See Table 8.9 in Chapter 8.

Table 5.6:

Correlations *r* between mathematics examination results and independent variables

		Pretest reading	Posttest reading	Maths assignment mean	Matric English	Matric African
Mathematics examination	*r* coefficient sig.(2-tailed)	0,63** 0,000	0,48** 0,005	0,41* 0,01	0,24 0,18	0,25 0,25
Pretest reading	*r* coefficient sig.(2-tailed)	-		0,38* 0,04	0,27 0,16	0,34 0,15
Posttest reading	*r* coefficient sig.(2-tailed)		-	0,10 0,56	0,41* 0,02	0,26 0,24
Mathematics assign. mean	*r* coefficient sig.(2-tailed)			-	– 0,12 0,50	– 0,03 0,88
Matric English	*r* coefficient sig.(2-tailed)				-	0,60* 0,003
Matric African	*r* coefficient sig.(2-tailed)					-

*Correlation significant at the 0,05 level **Correlation highly significant at the 0,01 level

5.7.3 Programme evaluation results

The reading activities had been roughly separated into 'general' reading (implying that mathematical text was not specifically used) and 'mathematical' reading. Students ranked contrastive relations and academic vocabulary highest with respect to relevance of general reading activities; the PQ4R strategy, and the notion of creating context through the use of diagrams, were ranked highest with respect to specifically mathematical reading activities.

The two most frequent responses to the open-ended questions on the helpfulness of the programme were increased ability to understand the study guides, and increased ability to follow instructions and analyse questions.

5.8 Discussion

While the importance of reading in the social and human sciences seems undisputed, it has often been assumed that mathematical success requires primarily logical reasoning and numerical skills. Consequently, the role of reading in constructing meaning in mathematics is often underestimated. It is important not to over simplify the problem. Many people with poor reading skills are good mathematicians; many people with excellent reading ability do not cope with mathematics. There are obviously many different factors involved, not least of which are the issues of motivation, patience, persistence and other cognitive aspects uniquely (perhaps) associated with mathematical argument. The concept of multiple literacies is also relevant, since being a ‘good’ reader does not necessarily imply being a good reader in a particular academic content area. However, in this study it is the converse that is more to the point: unless students reach a particular reading threshold, they will be unable to cope with their mathematics (and possibly with other subjects as well).

Phase I results suggest a robust relationship between reading ability and academic performance in mathematics. Students who failed their mathematics examination had considerably poorer reading skills than those who passed. Phase II corroborates the findings from Phase I: good reading ability cannot guarantee mathematical success but the results suggest that poor reading ability may be a barrier to effective mathematics performance.

Most of the skills investigated were lacking at the start of Phase II, although there was evidence that some were slowly being acquired by the time the students were tested in August. We briefly review theses skills.

Reading speed

The students were not *studying* the text used in the pre-and post-testing, but reading it in order to answer questions. Expecting a reading rate of about 160 wpm for these L2 readers seemed reasonable, but the average reading rate *after* the intervention was still only 136 wpm (Table 5.4).

Anaphoric referencing

Skilled readers resolve anaphors with at least 95% - 100% accuracy. The results indicate that many of these mathematics students had problems with anaphoric resolution, and were thus likely to keep ‘missing the point’. This undermines comprehension, and hence the ability to *read* to *learn*. From Table 5.4 we see that student ability to handle anaphoric reference improved from a mean of 46% in the pretests to 61% in the posttest, still too low for efficient text comprehension.

Logical relations

Semantic relations in text weave ideas and arguments together and give the text coherence. Readers need to perceive such relations in order to construct a coherent representation of the text. In Phase I the Pass students were much better at perceiving such relations than the At Risk students, who in turn were better than the Fail students (see Figure 5.2). In Phase II students also scored poorly in this aspect of reading (and improved relatively little, from a mean of 39% in the pretest to 47% in the posttest[13]). Given the importance of causal, conditional causal and contrastive relations in mathematics, it is clear that students who skim the text and look only at what they perceive to be the essential mathematics (i.e. equations, calculations, etc.) will be unable to develop conceptual understanding.

Vocabulary

Vocabulary levels improved little during the intervention phase, in spite of increased exposure to academic text over the same period.

The main research question of Phase II was: Does explicit attention given to reading help students learn mathematics more effectively? The posttests showed that most *reading skills* did improve during the intervention. However, because no posttest results were available, it cannot be claimed that the improvement was specifically due to the intervention programme. Other contributing factors, such as maturity, increased exposure to mathematics discourse during the year, or improved study skills may have played a role. However, reading is a specific cognitive-linguistic skill, and reading research consistently shows that reading only improves if students engage in reading practices. The pre- and posttests targeted specific components of reading ability and it is unlikely that such specific reading skills could have improved through maturity alone, or as a result of an improvement in general study skills.

An intervention programme should also aim to influence students' attitudes towards reading and raise awareness of the extent to which low reading levels constitute a barrier to academic success. Reading research shows that weak readers do not always realise that they have a reading problem, and cannot always utilise repair strategies to remedy their lack of comprehension (e.g. Oakhill & Cain, 1997). The results of this study showed that in evaluating their own reading ability, many students felt that they did not have a reading problem, even though they had scores of below 45%. Initially over 50 students volunteered for the intervention programme, but many misunderstood the purpose of the programme and dropped out early. For example, one student saw no reason to attend, stating 'I am not satisfied with this programme because we are not doing any real maths, we are doing just words, so how are we supposed to do our assignments?' Another student, on being told that the programme was about reading, replied: 'Reading? What's the big deal? I want

[13] In retrospect, it was unfortunate that the tests were designed in such a way that logical relations and graphs were tested in the same section, as it was subsequently not clear from the data whether a low mark reflected an equally low score in both aspects considered, or a particularly low score in one and a reasonable score in the other.

mathematics'. However, during the 22-week intervention period it became clear that students were starting to recognise that reading was crucial to understanding. Thus also from an affective point of view it appears that students can benefit from explicit instruction in which the importance of reading is stressed, and general reading skills and subject-specific reading strategies are taught.

Could the improvement in reading translate into improved *mathematical performance*? Phase I results indicated that a student whose overall reading ability was below 60% would probably fail, and that a student who achieved less than 46% would fail hopelessly. These findings were corroborated in Phase II of the study. As Table 5.5 and Figure 5.3 indicate, the students who failed outright only achieved an average of 47% in the posttest, while the students who gained admission to the supplementary examinations (but still failed) achieved an average of 52,3% in the posttest.

It is important to avoid unrealistic expectations as to what a reading intervention programme can achieve. The mean reading score of the group was extremely low to begin with, and after a 22-week intervention programme students only reached a mean comprehension level of 56 % (see Table 5.4). Thus, even after the intervention programme, the majority of these students were still reading at well below their maturational levels. This highlights the severity of the reading problem, and the limited potential of short-term interventions. Although the results of the five-month intervention programme were encouraging, the students were still averaging reading skill levels comparable to Fail students (i.e. below 60%). Most of the students would have benefited from a more intensive (i.e. more hours a week) and longer (e.g. for a full year, at the very least) intervention programme. Unless students can improve beyond a 60% threshold it seems they are unlikely to be successful in studying mathematics in a distance-learning environment.

Table 5.6 raises interesting questions about assessing the competence of incoming students. University admission is largely based on matriculation results, yet the table shows a far higher correlation between reading pretest results and mathematics examination scores than between any other scores and the examination scores. It may thus be possible to give students more appropriate advice with respect to potential directions of study if they are first assessed in terms of different components of reading. This aspect will be taken up again in Chapter 9.

5.9 Summary

In this chapter we first considered briefly Phase I of the reading intervention. It involved the design and piloting of a reading test; reflection on the results led to a number of adaptations being made before the test was then administered to a large group of students. This cycle of planning, acting and observing thus led to Phase II of the reading intervention and the second cycle in this set of action research cycles. Phase II focused on an intervention programme involving 33 volunteer students, in a face-to-face context. UNISA is a distance learning institution, and the Mathematics Access Module attracts large numbers of students. The intervention described in this chapter thus reached only a very small percentage of the students. Reflection on the results suggested that a large-scale intervention might have an impact. This led to the next phase of the reading intervention, which focused on how the intervention could be extended to all Mathematics Access Module students.