LANGUAGE PRACTICES OF TRILINGUAL UNDERGRADUATE STUDENTS ENGAGING WITH MATHEMATICS IN KENYA

by

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DECLARATION

I declare that **Language Practices of Trilingual Undergraduate Students Engaging with Mathematics in Kenya** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete referencing.

....   8 / APRIL / 2016

Signature   Date

EVELYN WANJIRU NJURAI

Student number 47299878

DEDICATION

To

My Daughter

Rita Claudia Wambui

My Parents

Raphael. K Njurai (late) and Gladys Wambui Njurai

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I thank the Almighty God for giving me the opportunity, strength, guidance and grace to complete this PhD study.

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ABSTRACT

This study explored language practices of trilingual undergraduate students of mathematics as they made sense of an algebraic task. Specifically, the study set out to explore whether, how and why trilingual undergraduate students used language(s) to make sense of mathematics. In this study a trilingual speaker is viewed as an individual proficient in three languages and whose proficiency in the languages is not necessarily equal. The speaker uses the three languages either separately or by switching between any two in ways that are determined by his/her communication needs.

Exploring language practices helped me to understand how students position themselves as they engage with a mathematics task using mathematical Discourses (capital D) in relation to their trilingual language facility. This facility involves the use of either the language of learning and teaching (LoLT) (English) or the switching between two or three of the languages they know. These languages were home languages, including Kiswahili of the students. In tertiary institutions, English is the LoLT while the home languages are neither taught nor used in the classroom.

The study used a qualitative inquiry process, specifically a case study approach. It was conducted at a public university in Kenya with a focus on first-year engineering students with mathematics in their programme. Data were collected using a students' questionnaire, and clinical and reflective interviews. A structured questionnaire was used to gather the baseline data, which was used for the selection of 15 interview participants. The clinical interviews provided information on language use as the students engaged with the task, explaining each step of the process, while the aim of the reflective interviews was to identify, ascertain and confirm various actions and different languages and language practices that were not apparent during the clinical interview. The interviews were transcribed and 11 paired transcripts were selected for analysis.

The data were analysed using the methods of Discourse analysis (Gee, 2005). This analysis explored how students used language in tandem with non-language "stuff" in a single language or when switching between any two languages and how and why each was used. The focus was on the activities and identities they enacted through their interpretation of the given task and in part of the solution process.

The findings revealed that when students engaged with mathematics, they drew on the LoLT only, or switched between the LoLT and their home languages or between the LoLT, home languages and Kiswahili. Those who switched did so when they were faced with interpretation challenges, when there was need to emphasise a point and due to habitual practices of switching. They commonly switched silently and communicated verbally in the LoLT. The purpose for code switching was to gain understanding of the task. On the other hand, a trilingual student is likely to remain in the LoLT because content has been taught and tasks presented in the LoLT.

The key contribution of this study is its focus on the trilingual language context of undergraduate students of mathematics, an area that has not been researched up to now. Furthermore, this study has added to scholarly work in this discipline by establishing that code switching is not the preserve of students who are learning the LoLT; rather, it is a reality for trilingual students who are competent in the LoLT when they engage with mathematics.

KEYWORDS

Trilingual, bilingual, multilingual, code switching, Discourse analysis, mathematical Discourses, first-year undergraduate students, language practices, learning and teaching, home language, first language, Kenya

GLOSSARY OF TERMS

Additional language refers to any language acquired in addition to a speaker's first or home language (see first and home language below). It is also referred to as a second language.

Bilingual refers to an individual who acquires and is proficient in two languages (Grosjean, 1982, 1985). The proficiency in the two languages is not necessarily equal, but as dictated by the communication needs of the individual.

Code switching is the alternative use of two or more languages in an utterance or conversation in a more or less deliberate way (Baker, 1993; Grosjean, 1982). Elsewhere, language switching has been used to mean the use of two or more languages during solitary and/or mental arithmetic computation (Moschkovich, 2005). In either case, the switch may involve a word, phrase, part of a sentence, a sentence or several sentences. Since this study concerns instances both of verbal conversations involving language switching and non-verbal language switching (including mental computations), I choose to use code switching to refer to all situations where students switch between languages in verbal conversations and/or in mental computation or thinking.

First language refers to a language that a person acquires from birth (see e.g. Setati, 2002). Other terms used to mean the same include mother tongue, L1, vernacular and indigenous languages (see e.g. Clarkson, 2006; Cleghorn, Merrit & Abagi, 1989). In the context of this study, the first language is an African indigenous language. In the case of the trilingual students in this study, their first languages are identified. Related to first language is the home language.

Home language: refers to the language commonly used at home and in the larger community. In some works it is also referred to as main language (e.g. Adler, 1998). A home language may be the first language of a speaker or it may be another acquired language. For example Kiswahili, the national language of Kenya, is a home language for some communities who do not share a first language. Related to home language is predominant language (see below).

Multilingual refers to an individual who is proficient in more than two languages (see Chitera, 2009b; Setati, 2002).

Multilingual classrooms are classrooms in which multiple languages are represented (Adler, 1998).

National language is a language that represents the national identity of a country (Chitera, 2009b) and which is commonly used in public addresses and communication between different language speakers. For example, in Kenya, Kiswahili is the national language. It is also the language that unites the 42 different language communities. In some heterogeneous language communities, Kiswahili commonly emerges as the home language.

Official language is a language that is given a unique legal status for communication in a country (Chitera, 2009b). It is the language that is used in all official communications of government business such as in education and commerce. In Kenya, English and Kiswahili serve as the official languages.

Predominant language is the language that is used by the majority of people in the catchment area of a school. This is commonly the home language in such an environment.

Students and learners are terms that are commonly used interchangeably. They are both used to refer to individuals enrolled for the purposes of learning in primary, secondary and tertiary institutions (see e.g. Adler, 1998). The term pupil is also used in most cases to refer to primary scholars. In this study I have used the terms students and learners interchangeably but the particular participants in this study are referred to as students.

Trilingualism is the ability to speak three languages (Hoffmann, 2001; Ogechi, 2002). The speaker uses the languages according to his/her communication needs.

Trilingual speaker is here described as an individual who acquires and is proficient in three languages (Hoffmann, 2001). The proficiency in the languages is not necessarily equal. Further the languages are not of equal importance to the trilingual person; his/her use of the languages depends on the speakers' communication needs. The main distinction between trilingual and bi/multilingual speakers is quantitative in nature, which is the number of languages involved. Most students in Kenya start school as monolinguals or bilinguals; they acquire two or one language(s) respectively at school and hence they leave school as trilingual speakers.

ABBREVIATIONS

CAT	-	Continuous Assessment Tests
CRC	-	College Research Committee
JAB	-	Joint Admissions Board
JKUAT	-	Jomo Kenyatta University of Agriculture and Technology
KCPE	-	Kenya Certificate of Primary Education
KCSE	-	Kenya Certificate of Secondary Education
KEC	-	Kenya Education Commission
KIE	-	Kenya Institute of Education
KNBS	-	Kenya National Bureau of Statistics
KNEC	-	Kenya National Examinations Council
KUCCPB	-	Kenya Universities and Colleges Central Placement Board
LiEP	-	Language in Education Policy
LoLT	-	Language of Learning and Teaching
MoE	-	Ministry of Education
NCEOP	-	National Commission on Education Objectives and Policy
RoK	-	Republic of Kenya
UNESCO	-	United Nations Educational, Scientific and Cultural Organisation
UNISA	-	University of South Africa

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CHAPTER 1

SETTING THE SCENE

1.1 Introduction

My interest in the language practices of trilingual students stems from my experience first as a student and later as a teacher. I am a Kikuyu first language speaker. Kikuyu is also my home language. In my childhood, prior to going to school, I had little exposure to Kiswahili, the national language of Kenya. Schooling ensured improvement of my Kiswahili and acquisition of English, the only official language at the time, and the language of learning and teaching (LoLT) in Kenya. I had acquired a good command of conversational English, by local standards, by the middle years of my primary schooling. However, my proficiency in conversational English did not translate into favourable results in the subject either at primary or at secondary school level. My results were rather low compared to my scores in mathematics. While the English language results prevented me from pursuing subject combinations whose prerequisites were a credit or distinction in English language at high school, I pursued mathematics up to tertiary level and graduated as a mathematics teacher.

Upon graduating, I taught mathematics at high school level in Kenya. The students in the schools spoke a range of home languages but in each school, there was one predominant local language. Kiswahili and English were also taught to students but neither of these languages was the students' first or home language. In the course of my teaching, I realised that some of these students scored very high grades in mathematics compared to their grades in English. Interestingly, this was despite the fact that they were taught English as a subject and learnt all subjects, except Kiswahili, through the medium of English. Given the differences between the two subjects, I could not understand why students could excel in mathematics taught through the English language, yet still perform poorly in English as a subject. I wondered how they made sense of mathematics as their English results suggested that they were probably struggling to understand mathematics taught in this language.

The students and I were trilingual and shared some performance characteristics in the LoLT and mathematics; I wondered whether we shared similar experiences while engaging with mathematics. I had come to realise that as a student, both at high school and at university, I had at times engaged in mathematics through the medium of my home language, Kikuyu. This was not unique to me since during group discussions, my peers (with whom I shared my home language) and I discussed most of our mathematics work in Kikuyu. Given that English was not my students' home language I wondered whether, like me, they used their home languages to make sense of mathematics. This triggered my interest in the language practices of trilingual students who are competent in mathematics. I was specifically interested in how trilingual undergraduate students of mathematics used their languages to engage with mathematics tasks.

My concern with the language practices of trilingual students is in keeping with the need for research related to the use of languages other than the use of students' first languages as the LoLT, as suggested during a symposium on "Interactions between Linguistics and Mathematical Education" held in Nairobi in 1974 (UNESCO, 1974). The symposium (UNESCO, 1974) highlighted the need for research in a context in which the language of instruction is not the students' first language. The symposium report noted that when mathematical ideas are presented to multilingual students in an additional language, the students may relate them to how they can address them in their first languages. This need for research among multilingual students can partly be addressed through research into the language practices of trilingual[1] students, by viewing trilingualism as a special case of multilingualism.

[1] Trilingualism is discussed later in this chapter in section 1.2.1.

In the case of my peers and I who were exposed to three languages at school and drew thus on our home languages to engage with mathematics tasks, a range of language practices were bound to be evident, together with unreported challenges. This situation is common in the broader context of Kenya, where most students are exposed to three languages at some time during their schooling and have to deal with them. These trilingual students speak a variety of home languages; hence the mathematics classrooms are multilingual. Such students commonly deal with their three languages either explicitly or implicitly when engaging with mathematics. The language practices that emerge from the use of these languages have not been researched and therefore they present an area worth researching in the context of Kenya in particular. In fact, language practices of individual trilingual students in mathematics education have not as yet been explored. Thus this thesis partly attends to the research need identified during the UNESCO symposium (1974) in a particular case of trilingual undergraduate mathematics students in Kenya.

1.2 Problematising trilingualism in mathematics education

Success in mathematics (or lack thereof) has frequently been associated with proficiency in the LoLT (e.g. Howie, 2003; Mestre, 1981). However, success cannot be attributed only to language proficiency; there are other language factors that influence learning. For instance, how teachers draw on students' fluency in the LoLT (e.g. Setati, 2008) and how students draw on other languages at their disposal in order to make sense of mathematics problems (e.g. Adler, 1998; Moschkovich, 1999, 2002). This latter factor is the focus of the study reported on in this thesis.

The availability of more than one language in a classroom may open opportunities for the use of different languages for learning and teaching. In such situations, there are language practices involving one or multiple languages and associated discourses. Studies conducted in both bilingual and multilingual mathematics classrooms have shown how students' language practices which involve drawing on the languages at their disposal, support them to participate and improve their performance in mathematics (see, for example, Adler, 1998; Barwell, 2003; Moschkovich, 1999; Setati, 2005). These studies have focused mainly on two languages: the LoLT and students' home languages (Adler, 1998; Moschkovich, 1999; Setati, 2005) or on the LoLT only (Barwell, 2003; Mestre, 1988). The LoLT in most cases is reportedly not the students' home language, particularly in studies conducted in Africa. In contexts such as Kenya, India and Malawi, students also need to learn and gain fluency in a third language, referred to as the national language. These national languages, however, are not used as LoLT in mathematics classrooms (Chitera, 2009b). In these contexts, the occurrence of the third language makes the students trilingual (see Hoffmann, 2001). While research into language practices in mathematics education in bilingual and multilingual mathematics classrooms has recently increased in diversity and volume (see, Phakeng, 2013; Setati, Chitera & Essien, 2009), so far there have been no studies that address language practices of such trilingual students when they engage with mathematics. Thus in this study I seek to understand the language practices of trilingual students in Kenya by exploring whether, how and why these students who learn mathematics in a language that is not their home language draw on their other languages to make sense of mathematics. It should be noted that trilingual students may also have other languages in their repertoire, but the concern of this study is on the three dominant languages in their lives – the home language, the national language and the LoLT (each with a different status) – that mathematics students are exposed to at one time or another during their schooling and that they may draw on during their learning of mathematics.

1.2.1 Why focus on trilingualism?

Research into trilingualism is limited and no one definition of trilingualism has so far been adopted (Hoffmann, 2001). This limitation might be partly attributable to assumptions about trilingualism: that it is an extension of bilingualism or that it should be viewed as part of multilingualism (see for example, Beaten Beardmore, 1982 in

Hoffmann, 2001)[2]. Furthermore, there are implicit suggestions that several lingualisms can be subsumed under bilingualism or multilingualism. In an effort to identify different linguals, it is necessary to know the number of languages involved. In fact the fundamental distinction between trilingualism and bi/multilingualism is largely of quantitative nature that is trilingualism involves three languages while bilingualism and multilingualism involves two and multiple languages respectively.

Researchers in the area of trilingualism (Hoffmann, 2001; Ogechi, 2002) accept the quantitative aspect and note that there are also qualitative aspects that are characteristic of trilingualism (Hoffmann, 2001). Firstly, there are different groups of trilinguals, depending on both the circumstances and the social context under which they acquire and use the three languages. Hoffmann notes five groups; bilinguals who acquire a third language at school, bilinguals who acquire a third language through immigration, children who grow up in a bilingual community and the home language is different from the community languages, children brought up in bilingual families whose languages are different from the language spoken in the larger community, and members of trilingual communities. In my view, an additional group is that of monolinguals who acquire two languages at school. Secondly, a trilingual speaker uniquely uses his/her three languages in ways that are determined by his/her communication needs. He/she has the ability to function like a monolingual, a bilingual or a trilingual, depending on the topic, place or interlocutor. This requires a decision to code-switch (Hoffmann, 2001). Code switching is also a common characteristics among bilingual and multilingual persons (see e.g. Hoffmann, 2001; Skutnabb-Kangas, 1984 in Baker, 1993).

Given these quantitative and qualitative aspects of trilingualism, it can be observed that while a trilingual person may share some characteristics with a bilingual and/or multilingual person, a trilingual is not an extension of a bilingual but a special case of a

[2] In this thesis I have referred to a bilingual as an individual who acquires and is proficient in two languages (Grosjean, 1982, 1985) and a multilingual as an individual who is proficient in more than two languages (see Chitera, 2009b; Setati, 2002)

multilingual person with specific characteristics. These characteristics enable us to describe a trilingual speaker as one proficient in three languages and whose proficiency in the languages is not necessarily equal. The speaker uses the three languages either separately or by switching between any two in ways that are determined by his/her communication needs.

This understanding of trilingual speakers begs the question of language practices of trilingual students when they are engaging with mathematics; hence the focus on of this study. In the absence of literature that discusses trilingual students' language practices in mathematics education; in this study I draw on literature on language practices and mathematics performance in relation to the language competence of bilingual and multilingual students which have been widely researched to ground the problem of language practices of trilingual mathematics students in the Kenyan context.

1.2.2 Situating the problem

Studies in bilingual mathematics classroom contexts have explored students' participation and performance in mathematics (Clarkson, 1992, 2006; Dawe, 1983; Mestre, 1981, 1988). For example, Clarkson (1992, 2006) has shown that students who are highly competent in mathematics are proficient in both their home language and the LoLT while low performers in mathematics are not proficient in one or both languages. However, some studies have shown that students with low proficiency in the LoLT can also succeed in mathematics (Barton & Neville-Barton, 2003; Dlamini, 2009). In these later studies, students had limited LoLT (English) competence but these limitations did not prevent them from succeeding in mathematics. In fact, Barton and Neville-Barton (2003) working with undergraduate students went as far as to show that while proficiency in LoLT affects mathematical understanding; it is the understanding of mathematical English that is necessary for success in mathematics. What these findings imply is that competence in the LoLT may not necessarily be a predictor of mathematics achievement. In fact, from these findings, one cannot argue for or against students' language competence in the LoLT or home language as a predictor for success in mathematics. What issues in language could possibly then lead to students' success in mathematics? Research has further explored bilingual students' ability to interpret mathematics problems.

Mestre (1981, 1988) argues that bilingual undergraduate students who learn mathematics in a second language (the LoLT being English in this case) experience interpretation difficulties as a result of their low proficiency in the LoLT, leading to low performance in mathematics, while their monolingual English peers perform better. On the other hand, despite their high mathematical performance, bilingual students who perform well in the LoLT also face interpretation challenges in mathematics, for instance, tasks that are considered to be of advanced difficulty (Clarkson, 2006). In such instances, Clarkson (2006) observes that some students draw on their home languages to solve such problems. Given this scenario among bilingual students, one wonders what the language practices of trilingual students would be when faced with interpretation difficulties in mathematics.

Studies in multilingual contexts have mostly explored multilingual students' participation and performance in mathematics based on their proficiency in the prescribed LoLT and/or their home languages. According to Howie (2003), multilingual learners' proficiency in the LoLT is the most significant factor in explaining differences in students' mathematics scores, while fluency in the home language has no significant effect on these scores. The South African Language in Education Policy (LiEP) supports multilingualism, so students are also taught through the medium of specific home languages. While Howie's work was limited to a single language as the mediator of the multilingual learners' mathematical performance, it is likely that students' home languages had an influence on the students' mathematical performance.

Harnessing students' home languages as important resources for learning has been argued as a means to improve multilingual students' participation and performance in mathematics (see, for example, Setati, 1998; Setati & Adler, 2000). This is especially appropriate when they have limited proficiency in the LoLT, which may prevent them from expressing their mathematics ideas clearly. These studies show that exploring students' mathematical participation and performance by focusing on the LoLT and home languages broadens the view of understanding multilingual students' mathematical ability. However, this view remains narrow since multilingual students have other languages in their repertoire, as explained below.

While exploring code switching practices in a senior primary class in South Africa; Setati (1998) noted that the teacher and all the learners were multilingual, with Setswana as their first language, except in the case of one learner whose first language was Afrikaans. He could, however, understand Setswana. However, during learning and teaching, code switching by the teacher and the learners was between Setswana and English. This raises the question of whether the trilingual Afrikaans first language student explored meaning in his third language, Afrikaans.

In Catalonia, immigrant students with home languages different from the official LoLT, Catalan, were prevented by teachers from communicating their mathematical ideas because of their limited proficiency in the LoLT (Gorgorio & Planas, 2001). While their teachers acknowledged the diversity of languages and ways of knowing mathematics associated with the different home languages, they faced the challenge of accessing these students' thinking as a result of language differences. Thus the students' understanding of mathematics in their home languages remained inaccessible and unexplored.

Students' mathematical understanding has been investigated in the languages that are apparently allowed by policy, as discussed above. It has been established that students who are competent in the LoLT also draw on their home languages to make sense of mathematics. Students' understanding of mathematical concepts in their third language, which in some cases is their home language, has not yet been investigated. In my view, the lack of research in this area limits our understanding of these students' mathematical ability. Research should investigate how students use their other languages, their home languages and/or other national languages, to support their participation and performance in mathematical activities.

Chitera (2009a, 2009b) revealed that in teacher training colleges in Malawi where English is the LoLT, teacher educators provided opportunities for student-teachers to use their home languages. The Chichewa and Chitumbuka student-teachers had difficulties in expressing their ideas in English and were therefore allowed to express them in their respective home languages. In the multilingual context of Malawi, English is the official language and Chichewa the national language. While the use of the home languages was not supported by LiEP at college level, in this particular case their use was aimed at motivating and encouraging student-teachers' participation in the mathematics class. The language context of Malawian students is fairly similar to that of Kenya, where the study reported in this thesis was conducted.

The majority of Kenyan students become trilingual while at school. During the first three years of their schooling, students in Kenya are taught through the medium of their home language. During this period they are introduced to learning their home languages as well as Kiswahili and English as subjects. It is worth noting that while Kiswahili is the national language and is widely spoken, to some students it is as foreign as English (Ogechi, 2009). Such students come into contact with Kiswahili while at school. Research exploring the use of two languages, Kiswahili and English, for instance, or Dholuo and English, has been conducted, particularly from a teaching perspective (Bunyi, 1997; Cleghorn, Merrit & Abagi, 1989; Merrit, Cleghorn, Abagi & Bunyi, 1992). However, to the author's knowledge no previous research in Kenya or elsewhere has dealt with how individual trilingual students, use their languages when engaging with mathematics.

In summary, research works reviewed above have shown that competence in LoLT does not necessarily suggest students will succeed in mathematics. Further, there is a research gap into language practices in trilingual contexts (Phakeng, 2013) and particularly research on language practices of undergraduate mathematics students is limited. There is then the need to seek understanding on language practices of trilingual undergraduate students through whether, and if so, how and why, the students draw on their trilingual language facility to support participation and performance in mathematics. In view of this research gap identified, the current study exploring the language practices of trilingual students is justified.

1.3 Purpose of the study and research questions

The purpose of the present study was to explore whether, how and why trilingual undergraduate students use their languages to make sense of mathematics. The three languages that the study focused on specifically are: the students' home languages, the national language, Kiswahili, and the LoLT, English[3]. Neither Kiswahili nor English are first languages for the majority of Kenyan students.

The study was guided by the following questions;

1. How do some trilingual undergraduate students in Kenya use their languages when solving mathematics tasks?
2. What language practices do these trilingual undergraduate students use when engaging with given mathematics tasks?
3. Why do these students use their languages as they do?

The questions focused on the students' language practices through their verbal and non-verbal expression, actions and reflections on their linguistic train of thought while they engaged with a mathematics task. A brief description of the theory that informed the study is presented below.

[3] Further details of how these languages are positioned in Kenya's LiEP at different times are discussed in a later section of this chapter in section 1.5.

1.4 Theoretical orientation

This study draws widely from Vygotsky's (1986, 1978) socio-cultural perspective and the analysis follows Discourse analysis (Gee, 2005). The Vygotskian socio-cultural perspective examines the roles of social and cultural processes as mediators of human activity and thought (Vygotsky, 1986, 1978). According to Vygotsky (1986), human thought realises itself, and is expressed, in words;

> the relation of thought to word is not a thing but a process, a continual movement back and forth, from thought to word and word to thought [...]. Thought is not merely expressed in words; it comes into existence through them (1986:218).

This suggests that thought and word can be regarded as in a reciprocal relationship. According to Vygotsky, the mediation of the interactional process of thought and word occurs through culturally constructed artefacts including psychological tools, symbols, and more elaborate sign systems such as language. Furthermore, language expresses thoughts through verbal and non-verbalised communication, that is, in spoken and written language, and gestures, while other thoughts remain unexpressed outside the human person (Vygotsky, 1986, 1978). These expressions can be found in the interactions within and between human beings, and between human beings and objects, that is, socio-culturally constructed artefacts. According to Vygotsky, language mediates human thinking and social interactions, that is, communication within and between humans. Trilingual students in this study explained how they used languages to interact within themselves, in thinking, and between themselves and others, by speaking and through non-verbal means when they engaged with a mathematics task. Their language practices will be analysed using Gee's Discourse analysis.

While Gee (2005; 2011b) acknowledges language as a tool for communication (speaking, writing and thinking), he sees the primary functions of language as supporting performance of social activities and identities and human affiliation within cultures, social groups and institutions. He argues that when we speak or write, we use language to project ourselves as certain kinds of persons engaged in certain kinds of activities (Gee, 2005, 2011a). In other words, language supports how we act according to certain identities engaged in certain activities, and hence we are associated with groups whose members act as we do. According to Gee (2005, 2011a), in using language, we enact certain Discourses[4] in the same or different contexts. He argues that Discourses can be understood by situating meanings of words in specific contexts of use. In order to make sense of the situated meanings, we need to select the patterns and sub-patterns that are relevant in a particular context. The guide to the selection of the patterns resides in Discourse models of a person's socio-cultural group and the social practices and settings in which this is rooted (Gee, 2005, 2011a). Gee's Discourse analysis can be used to analyse language practices within one or a multiple language environment.

Using Gee's Discourse analysis, the language practices of some trilingual undergraduate students were analysed in this study in an effort to communicate the socially situated identities and activities that students enacted as they engaged with a mathematics task. This analysis helped to understand whether, how and why trilingual students use language as they do when they engage with mathematics tasks. This theoretical framework is elaborated on in Chapter 4.

The findings of this study are particularly relevant to the Kenyan multilingual context, where most students are exposed to three languages at school. Furthermore, the study contributes to the global debate on language practices among students who are users of more than one language. The relevance of this study is discussed in the next section.

1.5 Rationale for this study

The rationale for this study is presented from two points of view: from the background of the study and from the context of past research on mathematics education and language diversity. The background underlines the relevance of the study in the context

[4] Reference is made to Discourse with capital "D". More details on Discourses are discussed in Chapter 2 section 2.2.2 and 4 section 4.3.2.2.

in which it was conducted. It is here that a brief historical perspective of Kenya's LiEP is presented. This brief account serves to show how English, Kiswahili and the students' home languages are positioned in the reports of different commissions on LiEP. The recommendations of these commissions have shaped discourses on language and language use in mathematics learning and teaching in Kenya and thus also the language practices of students who participated in this study. The rationale presented in relation to past research on mathematics education and language diversity highlights the need to conduct this study at this particular juncture.

1.5.1 Rationale by way of background

1.5.1.1 A brief geographical and linguistic profile of Kenya

Kenya is in the eastern part of Africa. Her neighbour to the south is Tanzania, to the west, Uganda, to the north-west, South Sudan and to the north, Ethiopia. To the east lie Somalia and the Indian Ocean. Kenya's population stands at about 39 million, made up of 42 tribes[5] (Kenya National Bureau of Statistics [KNBS], 2010). These tribes comprise speakers of English, Kiswahili and the main indigenous languages. English and Kiswahili are the official languages; Kiswahili is also the only national language (Republic of Kenya (RoK), 2010). The fact that English is an official language stems from the colonial history of the country. However, the country has few speakers of English as a first language (KNBS, 2010). Kiswahili, which is an indigenous language, functions as the lingua franca among the majority of indigenous language communities. The major indigenous tribes include the Kikuyu, Luhya, Kalenjin, Dholuo, Kamba and Ekegusii, while the minor tribes include Kiswahili, Gabra, Orma and Rendile (KNBS, 2010). Historically, speakers of all the different languages had regions that they initially occupied predominantly; free movement, however, created and continues to create communities of people with different first language backgrounds.

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[5]Languages are enumerated in terms of tribes in Kenya and hence the reference.

1.5.1.2 A brief historical perspective of Language in Education Policy (LiEP) in Kenya

During Kenya's colonial days, there was patronage by the British as colonists of Kenya. This ensured the high status of their language, English, in administration, business and education. During this period, the LiEP varied with time and the interests of the colonisers (Mazrui & Mazrui, 1995; Mbaabu, 1996; Nabea, 2009). Generally, English, Kiswahili and the main indigenous languages were used as LoLT. The indigenous languages were commonly reserved for the lower primary levels; Kiswahili was used in the middle levels, while English was used in all the upper levels, including university.

Kiswahili became the casualty of policy change and was scrapped as LoLT and as a subject at school (Chimerah, 1998; Mazrui & Mazrui, 1995). This occurred because the colonisers felt that Kiswahili could be used against them by the masses since it served as the lingua franca among all the African language communities and was therefore the unifying language. The teaching of Kiswahili was also believed to interfere with the learning and teaching of English by Africans (Mbaabu, 1996). According to Mbaabu (1996), poor performance in English among Africans during the colonial period prompted them to demand that they be taught in English. They had come to realise that knowledge acquired in the English language was a sure ticket to white collar employment and wealth (Nabea, 2009). There were similar circumstances in South Africa under apartheid regime, when African nationalists fought against the use of indigenous languages in learning and teaching because they saw it as a means of ensuring that they remained oppressed and excluded from gaining access to important social goods (Setati, 2008). In consideration of these factors and prior to independence in Kenya, English was promoted as the language of learning and teaching from Standard[6] One, while Kiswahili was dropped from the school system except where it was an indigenous language (Mazrui & Mazrui, 1995; Mbaabu, 1996; Nabea, 2009).

[6] In Kenya, the primary school levels are referred to as Standard 1, 2 …8. Standard 8 students graduate to secondary Form 1 and proceed through to Form 4. The Form 4s graduate to tertiary institutions.

When Kenya attained independence in 1963, English was declared the official language in all important government sectors, education included. Kiswahili continued to function as the national language and as the lingua franca for many Kenyans (Mazrui & Mazrui, 1995; Mbaabu, 1996; Nabea, 2009). During this period of early independence, the government realised the imperative of having a locally tailored Language in Education Policy (LiEP) to suit the needs of its citizens. It therefore appointed various commissions to review the existing LiEP. Some of the recommendations made by these commissions have shaped the LiEP at various times in the history of independent Kenya. In the next section the recommendations made by three of these commissions are discussed.

Kenya Education Commission (K.E.C), 1964

In 1964, the Kenya Education Commission (K.E.C) was tasked with surveying, among others, language resources in Kenya and advising the government on the formulation and implementation of national policies for education (Eshiwani, 1993; Mbaabu, 1996; Shiundu & Omulando, 1992). According to these authors, the commission established that the majority of Kenyans were in favour of English as the LoLT from lower primary up to university level. Furthermore, the commission felt that Kiswahili deserved to be taught as a compulsory subject because of its useful role in citizenship as a unifying language and as the regional lingua franca. The indigenous languages were found to be essential for storytelling. The commission thus proposed a period for storytelling or similar activities during which other indigenous languages would be used.

A number of reasons were cited in support of these recommendations. On one hand, it was the view of the commission that by making English the LoLT, students would be equipped with superior language proficiency and a corresponding improvement would be realised in the quality of post-primary education (Republic of Kenya [RoK], 1964, in Mbaabu, 1996). According to Mbaabu (1996), the commission felt that Kiswahili could not be used as LoLT because of the cost implications. Furthermore, there was the view that Kiswahili was not, at the time, in a position to accommodate scientific and technological terminology (Mbaabu, 1996). Mbaabu observes that this lack of clarity on the status of Kiswahili as LoLT influenced the level at which it's teaching as a subject was to start. It was also not examinable at the end of primary education; the result was that some primary schools avoided teaching it at all. However, it was made a compulsory subject at secondary level. In addition, the commission recommended that the use of indigenous languages continued in the historical role of providing a means of social communication (RoK, 1964, in Mbaabu, 1996). The commission viewed the vernaculars as ill-adapted mediums of instruction even in the critical early years of schooling (Mbaabu, 1996; Shiundu & Omulando, 1992).

In my view, while the importance of English as established by K.E.C may not be overemphasised, the commission failed to appreciate indigenous languages as important resources that could be used to support the learning of mathematics in English[7]. At the time, as is the case now, most students came into contact with the English language for the first time at school. Thus they needed to learn to speak and understand English at the same time as they learned and used it to learn other subjects such as mathematics. Given the fact that Kiswahili had developed as the lingua franca, advantage could have been taken of this by using it as the LoLT. The reasoning that Kiswahili and the indigenous languages could not accommodate scientific and technological terminology was not supported by evidence; because the fact that language develops through use was not considered. Currently, Kiswahili terminologies have been developed in computer technology, for example, and these are in use on the internet (Chimerah, 1998; Mazrui & Mazrui, 1995). The majority of the indigenous languages in Kenya were relegated to spoken communication. Generally, the recommendations of the commission differed little from colonial language policy.

[7] Research in linguistics shows that home languages can be used to support learning of an additional language and subject

National Committee on Educational Objectives and Policies (N.C.E.O.P) of 1976

The recommendations of the National Committee on Educational Objectives and Policies (N.C.E.O.P) of 1976 (Gachathi Report of 1976, in Mbaabu, 1996) took into account the need to use the language spoken predominantly in a school's catchment area. It recommended the use of this language as LoLT for at least the first three years of schooling, with English as LoLT from Standard four to university. In reality, the predominant language was the home language in the school's environment. It was also recommended that English be taught as a compulsory subject up to Form four at secondary school (Eshiwani, 1993; Mbaabu, 1996).

The commission recommended that Kiswahili should be introduced as a subject in Standard four. This was to avoid students in Standard one having to learn two new languages simultaneously. This recommendation, as Mbaabu (1985, 1996) observes, caused imbalances between urban and rural students in the level at which the learning of Kiswahili would start; Kiswahili was regarded as the predominant language in urban areas and was used as the LoLT in the first three years of schooling. This contrasted with the fact that it was not the predominant language in most rural areas and was thus taught as a subject. This recommendation also seemed impractical, given that all schools followed the same syllabus.

Other than the shortcomings regarding Kiswahili, the committee was specific about the class level at which English and the indigenous languages should be used. The majority of its recommendations were implemented and remain in the present LiEP (Mbaabu, 1985, 1996).

In the recommendations of the K.E.C and N.C.E.O.P, the position of Kiswahili as LoLT and subject was not clear. As much as it was the lingua franca, and had also developed as a first language for some students, especially those in urban areas and other linguistically heterogeneous communities (Mbaabu, 1996), its use in the school system

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matter taught in it (see e.g. Cummins, 1979).

was unclear. Its status in education gained ground only after recommendations were made by the Mackay Commission (Report) of 1985.

Mackay Commission (Report) of 1985

This Commission found that many university graduates could not communicate in the national language, Kiswahili (Mbaabu, 1985, 1996). According to Mbaabu (1985, 1996), this fact, among others, strengthened the commission's recommendation that Kiswahili be made a compulsory subject from Standard One to university. The commission further recommended the introduction of an African Language Division that would incorporate Kiswahili and other indigenous languages in the second public university (Moi University). Following these recommendations, the Department of Kiswahili was established at Moi University, with the aim of teaching of Kiswahili throughout the university; however, the teaching of other African languages did not materialise (Mbaabu, 1985, 1996).

Current status of LiEP and associated concerns

Following the recommendations from the various commissions, the current LiEP is such that students in lower primary (Standards One to Three) are taught in the predominant language of the catchment area of the school, followed by a shift to English in Standard four. The respective predominant languages are taught as subjects up to Standard three and English and Kiswahili are compulsory and examinable subjects from Standard One to Form four. While Kiswahili is the lingua franca and the national language, there is evidence that in some schools Kiswahili is not used as a language of communication outside Kiswahili lessons (Cleghorn et al., 1989). While noting that the wide use of Kiswahili may not necessarily translate to proficiency in the language, it is my view that Kiswahili could be used as a resource for learning and teaching in Kenya's multilingual classrooms. According to the policy, learning and teaching from Standard Four is meant to be in English.

This discussion makes it clear that English has dominated as the LoLT across all levels of education, and the indigenous languages are used only in the first three years of schooling. Recommendations that Kiswahili be taught as a subject have meant that it has become a compulsory subject through all 12 years of basic schooling.

Kiswahili was elevated to the level of an official language in the recently enacted new constitution (RoK, 2010). With official status, one would expect that Kiswahili would be used legitimately in learning and teaching, just as English is used. For example, education materials would be printed in Kiswahili, Kiswahili would be used as LoLT and as the language of assessment. However, Kiswahili is still treated as a subject, with limited use outside Kiswahili lessons, and English remains the dominant LoLT. While some members of the 10th parliament have argued vociferously, based on the constitution (2010), that only Kiswahili and English should be used in public offices (Daily Nation Newspaper, 10th June 2011), debates on the use of both official languages as LoLT have not surfaced. At this juncture it is important to ask why Kiswahili has not been functionally positioned as an official language of learning and teaching. This study provides insights on whether, how and why students may use Kiswahili while engaging with mathematics. The insights point to some reasons why Kiswahili should be used in learning and teaching.

Although the constitution embraces support for Kiswahili in particular and other indigenous languages in general, there are differing views on language use in the employment sector. The majority of people in Kenya view English as the language of the elite and the educated (Mbaabu, 1996). This view is similar to that in South Africa, where it is reported that teachers and learners regard English as the language through which one is likely to gain access to social goods, such as employment (see Setati, 2008). General employment in Kenya requires that potential employees, for example mathematics teachers in government institutions, have adequate command of the English language (Daily Nation News Paper, 20th Dec 2012). Proficiency in other languages, including Kiswahili, is stated as an added advantage and not a compulsory or necessary condition, and there is no space for the indigenous languages. Proficiency in Kiswahili is given a secondary position in most employment. With this attitude, the majority of parents make every effort that their children learn and are taught through the medium of English from kindergarten level.

This discussion of the recommendations of different education commissions shows how English, Kiswahili and the indigenous languages have been positioned in reports of commissions into the LiEP in Kenya since independence. What is clear is that the position of English as the LoLT, especially from Standard Four onwards, is dominant. It is regarded as the accepted language of teaching. Kiswahili was initially regarded as a non-subject, but was later upgraded to a compulsory and examinable subject, at least in basic education. With its current status as an official language, the question is whether it will become a LoLT, alongside English. Learners' home languages have been relegated to learning and teaching in the initial years of primary schooling.

While appreciating that implementation of language policies is not a straightforward matter, one wonders whether there is a possibility that Kiswahili could become the LoLT in future. Furthermore, one wonders what the future in education of other home languages will be, as more people move to urban centres where Kiswahili is the home language while in rural areas language heterogeneity assumes a more dominant position. In the discussion that follows I describe the language infrastructure of students who pass through the education system in Kenya.

The trilingual language context of students in Kenya

It has been observed that students who enter Standard One with the ability to use their first language only (as monolinguals, in other words) acquire Kiswahili and English at school. For instance, a student who enters school having acquired Kikamba only learns Kiswahili and English from the earliest moments. Others start school with the ability to use both their first language and Kiswahili, and then add English to their repertoire. For instance, a student may start schooling with the ability to use Dholuo and Kiswahili, and will then and acquire English at school. The latter is consistent with the way bilinguals acquire their third language, according to Hoffmann (2001). These two groups of students are by definition trilingual students, irrespective of the time and sequence of language acquisition. In the case of students whose first language is not Kiswahili, their first language is to a large extent replaced by the LoLT as they advance at school (see for example Lambert, 1975 in Cummins, 1979; 1981). Thus their first language does not develop academically beyond Standard Three. A student whose first language is Kiswahili, on the other hand, acquires English and becomes bilingual. However as discussed in section 1.5.1.1 above, there are very few speakers of Kiswahili as a first language. For this reason, the majority of students in Kenyan schools are trilingual.

Some questions arise about the trilingualism of the students described here. While such students' home language and Kiswahili are not prescribed for use in the learning and teaching of mathematics after Standard Three, could these languages be useful resources in such learning and teaching? In particular, do undergraduate trilingual students in Kenya use these languages while they engage with their individual mathematics work? If so, how and why do they use them?

1.5.1.3 Current language practices in mathematics and science classrooms

As in other language policy settings, implementation of the LiEP in Kenya has not been and is not a straightforward process. It is implemented differently in various language areas. Research shows that language policy and practice differ in Standard Four and beyond (Bunyi, 1997; Cleghorn et al., 1989). These studies show that while policy does not advocate for the language practice code switching, the practice is a reality in classes where English is meant to be the sole language of instruction.

Cleghorn et al. (1989) found that code switching was prevalent in a Standard Eight class in a school located in rural Kenya. In this school in Nyanza Province, Dholuo was the predominant language. The shift to English in Standard Four was gradual, with substantial Dholuo-English switching. Cleghorn et al. (1989) noted that, while teaching a science lesson in English, the teacher often incorporated local Dholuo words to render the content of the lesson more familiar. The authors postulated that the use of local and familiar words may have expanded students' awareness of word meaning and language differences, helping them to develop their English competence while also fostering understanding of the concepts that were being taught. However, it was observed that Kiswahili was not used outside the Kiswahili lessons. This use of the learners' home language was in contrast to the exclusive use of additional languages in schools located in the peri-urban and urban areas in the same study.

Cleghorn et al. (1989) found that code switching was not common in either peri-urban or urban schools. Rather, meaning making of science concepts in Standard eight classes in these schools was achieved strictly in the LoLT, and this was the only medium of instruction. Kiswahili was, however, used for other school functions outside the classroom. Cleghorn et al. (1989) surmised that the exclusive use of English in these two schools may have increased the learners' exposure to the English language and possibly accounted for the better performance of the urban school in the national examination. However, this adherence to national language policy disadvantaged the majority of the students in the peri-urban school, who spoke Kikuyu as their home language. The authors observed that in this school, making connections between science concepts in Kikuyu could have better established the meaning of abstract concepts.

In conclusion, it is clear from the discussion above that the teaching in peri-urban and urban schools in Kenya was strictly in English; however, it is possible that learners in the peri-urban school would have made better connections and established meanings of abstract science concepts in their home language. In the rural school, code switching was practised with the intent of assisting learners to understand their subject matter. It is possible that in the initial three years of schooling, some learners may not have developed adequate knowledge and skills in English to learn and follow instructions or to participate in English-only classes. With this awareness, teachers switched between learners' home languages and the LoLT to foster learners' understanding of concepts in the curriculum.

This section has shown that, despite the fact that students are trilingual; these studies at primary school level do not reflect how trilingual primary school pupils use their languages.

1.5.1.4 Towards university education

Learners who succeed in the Kenya Certificate of Primary Education (KCPE) in Standard Eight gain admission to secondary schools. In secondary schools, there is a strict administrative obligation as well as prestige in the use of English for all communication. While no research on language practices at secondary school level has been conducted in Kenya, anecdotal evidence shows that some teachers code switch to break the monotony of using English in the classroom and not necessarily to facilitate content acquisition among their students.

At the end of secondary school, a summative examination, the Kenya Certificate of Secondary Education (KCSE) is offered by the Kenya National Examinations Council (KNEC), the national examining body. When assessing students in English at Form Four level, it is assumed that they are competent enough in the LoLT to be assessed in it. After all, it has been the LoLT for the last nine years. The grades obtained in the KCSE determine the direction of a student's tertiary education.

Admission to undergraduate studies in public universities is based on merit and on the capacities declared by the universities through the Joint Admissions Board (JAB [currently renamed Kenya Universities and Colleges Central Placement Board, KUCCPB], 2010). The threshold grade required for admission is an aggregate of Grade C+, which is an average performance (see details in Appendix E). However, the cut-off grade and corresponding point for admission is revised every year by JAB (JAB, 1 Oct 2010). For example, for students who wrote their KCSE in the years 2009, 2008 and

2007, the cut-off point was a minimum of Grade B (plain) of 63, 65 and 66 points respectively (University World News, 22/9/2010).

Given the findings that policy and practice in Kenyan classrooms differ, and the fact that students are prepared differently to handle mathematics tasks presented in English, a key question in this study is how and why trilingual students use their home languages, Kiswahili and English to engage with mathematics tasks.

1.5.2 Rationale motivated by past research

Like the majority of Kenyan students, some students in Catalonia and some in Malawi are also trilingual. In Malawi, these students are those whose first language is not Chichewa. They acquire Chichewa, the national language, as a second language from the larger community, and English, the third language, from school. However, only the students' home languages and English are given recognition in the education system, with the former being used as the LoLT from Standard One to Four and the latter from Standard five to university (Chilora, 2000).

In Catalonia, both Catalan and Spanish are official languages (Civil & Planas, 2004; Gorgorio & Planas, 2001; Setati & Planas, 2012). Catalonia is an autonomous region in Spain. For some time Catalan was recognised as the sole LoLT in Catalan schools. In 2010, Spanish was recognised as a co-official language in the school system (Setati & Planas, 2012). However, as a consequence of political issues, Catalan still remains the LoLT while Spanish is learnt as a subject. In these Catalan schools, Setati and Planas (2012) note that a significant population is made up of immigrant students who are speakers of other languages, such as Arabic. By attending these schools, immigrant students learn in Catalan, and learn Spanish as a language. These students become trilinguals, starting school proficient in one language and learning two other languages at school.

While language policies in both Malawi and Catalonia facilitate students' trilingualism, research on mathematics education in the two contexts has focused mainly on bilingual and/or multilingual classrooms. In fact, even in other multilingual contexts (see e.g. Setati & Adler, 2000), where students are exposed to other languages, research has tended to focus on students' home language and the LoLT. Given these situations, the current study is significant in that it provides insights on whether, how and why trilingual students use their languages as they do when engaging with mathematics tasks. In the particular case of Kenya where policy places emphasis on the use of English as the only LoLT at university level, it is also important to understand how the national language and students' home languages are positioned when students engage with mathematics.

Research on mathematics education and language diversity locally and globally has been conducted mainly at classroom level, that is primary and high school (Bunyi, 1997; Planas, 2011; Setati, Adler, Reed, & Bapoo, 2002). Chitera, (2009a) takes the research into the context of teacher education. The study described in this thesis was conducted at university level. Findings could provide mathematics lecturers with a better understanding of what transpires linguistically in their trilingual students as they engage with mathematics tasks.

1.6 Conclusion

This chapter introduced the study by focusing on the motivation for undertaking the research on the language practices among trilingual undergraduate students of mathematics in Kenya. It explained that the majority of students in Kenya are initially exposed to three languages and thus become trilingual at school. Against this setting, a brief exploration of language practices in bi/multilingual contexts was presented. The exploration revealed that there is a research gap in the area of trilingual students in mathematics education, providing an opportunity for the current research. The purpose of the study was explained and the research questions guiding the study were outlined. A brief description of the theory that informed this study was provided and the rationale was explained. The remainder of the thesis is structured as follows:

Chapter 2 presents the first part of the literature review. It focuses on language, mathematics and performance, and on the relationship between language and mathematics. The chapter also provides insights into research on the influence of bilingualism on students' participation and performance in mathematics

Chapter 3 presents the second part of the literature review dealing with language practices of bilingual and multilingual students in their respective contexts.

Chapter 4 introduces the theoretical framework used to analyse the data. The framework is developed from Gee's theory of Discourse analysis

Chapter 5 presents the research design and methodology. This chapter covers the approach used, the sampling procedure and data collection methods, ethics, methodological limitations and validity.

Chapter 6 describes the transcription process, and provides an illustration of the process of analysis. The themes addressed in this study are also presented in this chapter.

Chapter 7 presents analysis of language practices in instances in which three trilingual students used English only to engage with the mathematics task.

Chapter 8 discusses the language practices of six students who used two languages to engage with the given mathematics task. The students functioned like bilinguals, using English and their home language.

Chapter 9 describes the language practices of two trilingual students who used their three languages to engage with a mathematics task. The languages were English, Kiswahili and the respective home languages.

Chapter 10 is the conclusion of this thesis. It provides an overview of the thesis, a summary of the findings and contributions of the study to mathematics education. This chapter also discusses the recommendations based on the findings, the limitations of the study and the conclusion.

CHAPTER 2

LANGUAGE, MATHEMATICS AND PERFORMANCE: INSIGHTS INTO THEORY AND PRACTICE

2.1 Introduction

In view of exploring the language practices of trilingual students, it is necessary to have an understanding of the relationship between language and mathematics, and the role that language plays in mathematics performance. This chapter therefore presents a detailed review of literature on the relationship between language and mathematics, and provides insights into research on how bilingualism influences students' participation and performance in this discipline[8].

The literature reviewed in this chapter includes research conducted in diverse educational, linguistic and geographical contexts. The literature is not limited to university education, where this study was conducted; rather, it draws from a range of education levels. The global focus on the development of research findings on bilingualism in relation to mathematics education necessitates that I review some literature that dates back to as early as the 1900s. The literature reviewed is, however, limited to works published in English.

2.2 Language and mathematics

Language is a natural human creation, with infinitely many meanings and combinations of meanings that can be expressed in one way or another through the medium of words and structures of the same language (Halliday, 1974 in UNESCO, 1974). Halliday (1974, in UNESCO, 1974) observes that each language exhibits this potential in a different way. One way of describing the relationship between languages, that is, a natural language like English, and mathematics, is in terms of the linguistic notion of register (Pimm, 1991). Halliday (1975 in Pimm, 1987: 65) argues that a register is "a set

[8] The issue of multilingualism in mathematics education is discussed in Chapter 3

of meanings that is appropriate to a particular function of language, together with words and structures which express the meanings". It expresses the social usage of particular words and expressions, ways of talking and ways of meaning within a specific social context. On mathematics register, Halliday (1975, in Pimm, ,1987) says,

> We can refer to a mathematics register, in the sense of the meanings that belong to the language of mathematics (the mathematical use of natural language, that is, not mathematics itself), and that a language must express if it is used for mathematical purposes [...]. It is the meanings, including styles of meaning and modes of argument, that constitute a register, rather than the words and structures as such [...]. We should not think of a mathematical register as solely consisting of terminology, or the development of a register as simply a process of adding new words (Halliday, 1975, in Pimm, ,1987: 65).

This suggests that a mathematics register has to do with how words and expressions are used in mathematics; styles of meaning and ways of arguing in mathematics. This register can be developed in any natural language, for instance, Kiswahili or English. Literature (Halliday, 1974 in UNESCO, 1974; Pimm, 1987; Rowland, 1999) describes some defining characteristics of mathematics register in relation to the English language:

- It consists of technical words and phrases that are unlikely to be encountered outside mathematics, for example *equation, hypotenuse* and *quadrilateral*.
- It has characteristic modes of arguing.
- It is not entirely impersonal, formal and exact.
- It contains some borrowed words such as *moment, mean, real, face, power, complete*, and *natural,* which have different meanings in the register from their original use.
- It contains certain whole expressions that are locutions whose meanings cannot necessarily be understood merely by knowing the meanings of individual words. Examples of such composite words and expressions include *square root, simultaneous equations* and *if and only if.*

- It sometimes deviates from ordinary English in particular sentence constructions less commonly employed in everyday speech, for example, the widespread use of the range of imperative forms such as *let, suppose, define* and *consider* as opening words in a sentence.

Pimm (1991) argues that part of knowing mathematics is acquiring control over the mathematics register so as to speak like a mathematician. A student should therefore learn to speak, listen, read and write like a mathematician using technical terms, phrases, symbols, abbreviations and ways of arguing that are unique to the subject. This includes differentiating words and phrases that have different meanings in mathematical language and in ordinary English. They should learn to use the language of mathematics and be able to construct, express and communicate the intended mathematical meanings (see e.g. (Pimm, 1981). As noted by Setati and Adler (2000), the reality is that speaking, listening, reading and writing mathematics in multilingual classrooms requires the use of the LoLT, in which students may not be fully fluent.

The borrowing that is characteristic of the mathematics register, though enriching, has the potential to cause confusion about the use and meaning of words and phrases that differ in mathematics and everyday English. Sorting out the multiple meanings of words in these two registers is part of knowing mathematics (e.g. Khisty, 1995 in Moschkovich 2002, 2003; Pimm, 1987). However, deciphering meaning is not a straightforward matter. An example of how confusion associated with the borrowings by the mathematics register can arise is provided by Pimm (1987), who highlights the sense of *evenness,* meaning the sharing of something equally between two people. In order to determine whether a number was odd or even, a teacher explained what it meant when a number of things were shared out between two people. If each person received the same amount then the number would be even, but if one item was left over, then the number would be odd. One pupil answered that his house number was 15, which was an even number because his family shared the house with the people upstairs. Similar misunderstandings are likely to arise with words and phrases such as *product*, *set*, *real*, *moment* and *quarter*. In this study, the students used words and phrases from the mathematics register when explaining how to work out the task that they had been given.

The discussion on the use and meanings of words and phrases that have different meanings in mathematics and in everyday register invites us to investigate the ways of knowing and meaning in mathematics. In particular, it leads to formal and informal mathematics language and how these are used in classrooms.

2.2.1 Formal and informal mathematics language

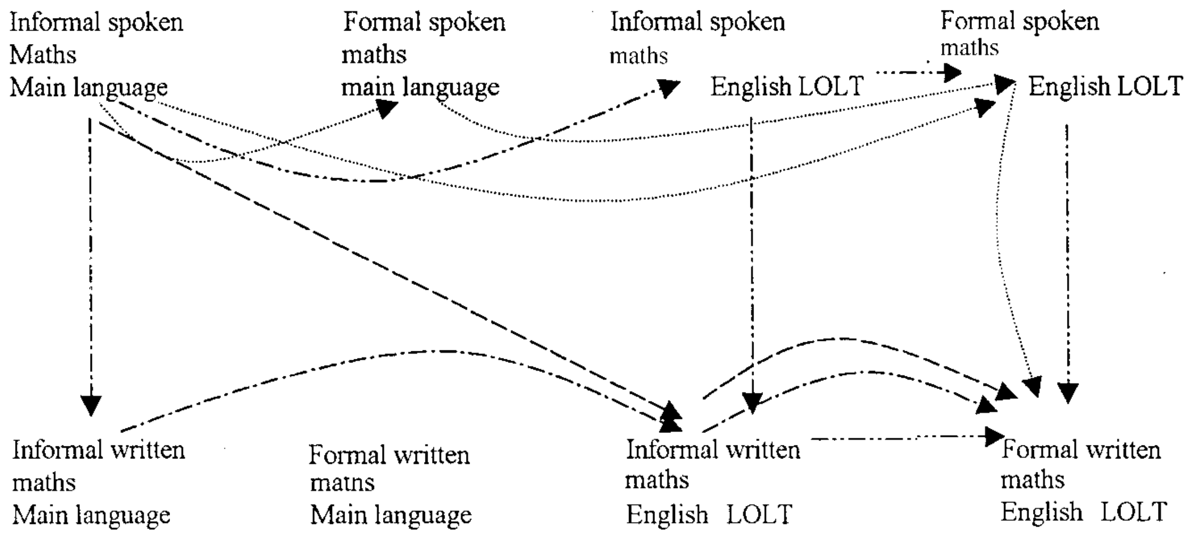
Students come to school with everyday ways of knowing, speaking, writing, listening and reading mathematics that are different from the formal ways of using the mathematics register and the language of mathematics. The classroom plays host to both these informal ways of knowing and formal mathematics ways of knowing that are expected in the classroom (Moschkovich, 2003;; Setati & Adler, 2000; Setati, Adler, Reed, & Bapoo, 2002).

According to Setati and Adler (2000), formal mathematical language refers to the standard terminology or mathematics register that has been developed within formal settings like schools. It is the language valued in school mathematics. On the other hand, informal mathematical language is the kind that learners use in everyday life to express their mathematical understanding. Based on what they have acquired and how they manipulated meanings as young children who were "learning how to mean", learners use their informal language in an attempt to assign meaning to unfamiliar mathematical phrases and expressions (Moschkovich, 2003). They draw on their experience with language(s) and the world to assign meaning to unfamiliar situations, including those in mathematics. Setati and Adler (2000) explain that "learners, in their everyday life, may refer to a half as any fraction of a whole and hence can talk about dividing a loaf of bread into three halves" (Adler, 2000: 249). This is informal talk that is inappropriate in formal mathematical talk and it is likely to cause confusion. However, they should not be viewed as obstacles to learning; rather, they should be regarded as valuable resources for developing learners' mathematical competence (Moschkovich, 2003). They can be used to assist learners in learning mathematics by moving from informal to formal forms of the language of mathematics that are valued in school mathematics.

Researchers have developed models that teachers can use to facilitate this development from informal spoken language to formal written mathematical language (Pimm, 1991; Setati & Adler, 2000). Pimm's (1991) model describes two possible routes; the first is to encourage students to write down their informal utterances and then to work on making the written language more self-sufficient. The second is to encourage students to work on formalising their spoken language and then writing it down. In suggesting these two routes, Pimm's model depicts a monolingual context where students are moving from informal spoken mathematics language to formal written mathematics language within the same natural language.

Setati and Adler (2000), working in a multilingual environment, show a variety of alternative routes that can be followed as learners move from informal spoken language to formal written language. They observe that these routes are complicated by the fact that different natural languages are involved. This situation calls for a longer route to achieving formal written mathematics than in a monolingual context. In their model, one possible route is to encourage learners to write down their informal utterances in the home language, then to write them in informal mathematical English and finally to work on making the written mathematical English formal (see Figure 2.1 below). In this case, the teacher works first with learners writing their informal mathematical thinking in both languages, and thereafter focuses on formalising and translating the written mathematics into the LoLT. Other possible routes are depicted in Figure 2.1.

Figure 2.1 Possible routes of moving from informal language in learners' home language to formal written language in English



Adapted from Setati and Adler (2000)

Both Pimm (1991) and Setati and Adler's (2000) models show the need for students to be able to communicate mathematics in both spoken and written forms. This necessity is emphasised by Pimm's (1991) observation of the apparent differences in the two modes of mathematical communication. He argues that when spoken, mathematics emerges as natural language; when written; it makes varied use of a complex, rule-governed writing system mainly separate from that of the natural language. Students therefore need to learn to decode the mathematics involved in both modes in order to communicate mathematics. The question that arises in this study is whether trilingual students use either or both formal and informal mathematics language.

Moving from informal to formal mathematics language involves learning mathematics within mathematics discourses. There are multiple and varied mathematics discourses. In what follows, these discourses are briefly discussed.

2.2.2 Mathematical Discourses

In this study, I used the notion of discourse as defined by Gee (2005). Gee makes a distinction between the terms discourse with a lower case "d" and with a capital "D". He refers to discourse as the language-in-use or the use of language "on site" (Gee, 2005: 7), and to Discourse as language plus "other non-language stuff" and thus states that Discourse is:

> ways of combining and integrating language, actions, interactions, ways of thinking, believing, valuing, and using various symbols, tools, and objects to enact a particular sort of socially recognisable identity (these are social practices) (Gee, 2005: 21).

This suggests that the meanings derived in any one Discourse situation are multiple, varied and situated in context of use. For example, "un cuarto" in Spanish means "a room" or "a fourth", depending on the context of use (Khisty, 1995, in Moschkovich, 2002: 194). In this case, as a Spanish student moves from informal to formal mathematics language, he/she needs to tease out the intended meaning of "un cuarto" within a specific mathematics Discourse.

Moving from informal mathematics language to formal mathematics language means that students are involved in learning standard terminologies or the mathematics register. The knowledge of the mathematics register facilitates mathematical conversations in the classroom (Pimm, 1987). In order for students to acquire this register, it is imperative that teachers teach from the basis of a conceptual curriculum[9] so that students come to learn and understand the intended curriculum (Thompson & Thompson, 1994).

In a conceptual curriculum the teacher provides and asks students for explanations in the process of solving a task (Thompson & Thompson, 1994). Alongside the conceptual orientation is the calculational orientation, which is viewed as composed of procedural steps of mathematical operations. The distinction between these two classroom orientations has been extended into calculational and conceptual discourses by Sfard, Nesher, Sreefland, Cobb and Mason (1998). These authors refer to calculational

[9] Conceptual curriculum is the curriculum in which teachers are sensitive to learners' thinking during instruction and shape their instructional actions accordingly in order to ensure that learners attain the intended concepts (Thompson & Thompson, 1994).

discourses as those discussions in which the primary topic of conversation is based on any type of calculational process. The conversation involves describing the specific steps that have been followed in arriving at a mathematical solution. However, this can be contrasted with a conceptual discourse in which the reasons for calculating in particular ways become explicit topics of conversation. In the latter case, conversations encompass both students' calculational processes and the interpretations of the tasks that underlie the ways of calculating.

Integrating the calculational and conceptual discourses at play with Discourse (Gee, 2005), it was relevant to this study to ask what Discourses accompany the conceptual and calculational discourses[10] as trilingual students respond to a mathematics task. In other words, when students explain their mathematical understanding conceptually and/or calculationally, in what ways do they integrate and combine language and "non-language stuff" to communicate this understanding? The notion of Discourses and hence mathematical Discourses is discussed in greater detail in Chapter 4.

This section on language and mathematics has highlighted the fact that language and mathematics are related in a complex way. Expressing their relationship in terms of a mathematical register involves expressions that go beyond words and structures and extend to styles of meaning and modes of argument. Students need to gain control of this register in order to use it in the manner of mathematically competent people. But while they need to learn the formal and valued mathematics register in school, they report to school with informal ways of knowing, and in different languages that are not necessarily valued at school. What is most important is to consider the mathematical Discourses within their communication, either in the LoLT or in their home language or both in order to derive the meaning of their utterances. In this regard, the present study analysed whether, how and why trilingual students use language to communicate mathematical ideas. The analysis will be drawn from mathematics register, formal and

[10]Calculational and conceptual discourses have been extended to procedural (in place of calculational) and conceptual Discourses (Discourses with upper case D) by Setati (2005) using the notion of Discourses (Gee, 1996).

informal mathematics languages and more particularly, from mathematical Discourses.

It is, however, important to note that both informal and formal mathematics languages are not natural languages in themselves; they are mediated through natural languages, for example English and Setswana. In this regard, a discussion on how natural languages influence students' mathematical communication became relevant to this study. In the following section, I discuss views of how bilingualism[11] influences learners' participation and achievement in mathematics. I start the discussion on a general note by focusing on bilingualism, and narrow it down to bilingual learners' mathematics performance in relation to language competence.

2.3 Language diversity and mathematics education: a focus on bilingual contexts

Research in mathematics education and language diversity can be traced back to studies on bilingualism and bilingual learners. Some early studies in this area show that bilingualism may have negative effects on bilingual learners and may be the cause of cognitive confusion and retardation in learners (e.g. Downing, 1974; Macnamara, 1967; Saer, 1923). Other related studies challenged this view and shown that bilingualism is an asset that provides support for both cognitive and linguistic development (see, Peal & Lambert, 1962, in Carringer, 1974). More recent works suggest that there is developmental interdependence between the languages of a bilingual that could be of benefit to him/her (Cummins, 1979). Research in mathematics education has used this notion to show that competence in the two languages influences a bilingual learner's mathematical performance (see e.g. Dawe, 1983). Further research has explored bilingual learners' mathematics performance when tasks are presented in their two languages (see e.g. Zepp, 1982). It is worth noting that research in mathematics education in multilingual contexts has supported the notion that learners' home languages are resources for learning and teaching mathematics as they increase in proficiency in the LoLT, which in most cases is not their home language (see e.g. Adler,

[11] Bilingualism is the ability to speak and write in two languages.

1997: 1998; Setati, 1998). These studies are, however, more recent than those involving bilingual learners. How the home languages are used in multilingual contexts is discussed in the Chapter 3, section 3.2 & 3.3.

In the next section, studies on bilingualism and learning are reviewed, as well as the influence of bilingual learners' language(s) competence on their mathematics performance, and later on mathematics performance when tasks are presented in two languages.

2.3.1 Research in bilingualism and learning: from detrimental to positive effects

The question of the potential effect of bilingualism on learners' language, cognitive and educational development has long been of interest to researchers. Early research in this area tended to focus on the challenges that bilingual learners faced when compared to their monolingual peers. For example, Saer (1923), working with Welsh-English bilingual learners aged between 7 and 12 years, showed that the learners performed poorly on verbal parts of intelligence tests, relying more on memory in their two languages than on reasoning. Furthermore, the different languages in their repertoire were found to cause mental confusion. In his work, Macnamara (1967) observed that bilingual students were slower than their monolingual peers in responding to arithmetic problems. He studied the effects of instruction in a weaker language among sixth form English-Welsh bilinguals. The weaker language in this case was the second language. Macnamara observed that although bilingual students translated words and expressions into their second language, the translation did not necessarily help them to decode the actual meaning. Thus Macnamara concluded that using such languages to teach students could result in retardation in subject matter knowledge. These studies suggested that bilingualism could have detrimental effects on students' intellectual functioning.

This notion had however been challenged before Macnamara made his observations and even after his observations by researchers who argued that rather than being a cause of mental confusion and retardation, bilingualism supported cognitive, linguistic and intellectual development (see, for example, Ianco-Worrall, 1972; Liedke & Nelson, 1968, in Swain & Cummins, 1979; Peal & Lambert, 1962 in Carringer, 1974; Swain & Cummins, 1979). For instance, in a study conducted by Peal and Lambert (1962 in Carringer, 1974), "balanced"[12] French-English bilinguals performed significantly better on both verbal and non-verbal intelligence measures than monolingual learners. This performance led Peal and Lambert to argue that bilinguals "have a language asset, a facility for concept formation and a greater mental flexibility than monolinguals" (Peal and Lambert, 1962 in Carringer, 1974:493).

Liedke and Nelson (1968, in Swain & Cummins, 1979) attributed French-English Grade-1 learners' better performance on a Piagetian concept formation task to the fact that they had been exposed to a wider range of experiences as a result of the greater social interaction involved in learning two languages. In his study, Ianco-Worrall (1972) observed that the majority of four to six-year-old Afrikaans-English bilinguals had a greater ability to interpret similar words than monolinguals because they perceived the relationship between words in terms of their symbolic or conceptual relationship rather than their acoustic properties. Furthermore, bilingual learners have a more analytical orientation towards linguistic and perceptual structures than monolinguals (Cummins & Mulcahy, 1978; Ianco-Worrall, 1972) and they may engage in diverse ways of expressing the same idea by comparing differences and similarities in their two languages (Ianco-Worrall, 1972; Lambert & Tucker, 1972, in Cummins, 1979).

These findings suggest that bilingualism is not necessarily an impediment to learning; rather, there are some positive benefits to being bilingual. A bilingual learner's language facility provides the individual with greater options in concept formation, and increased mental flexibility in expressing his/her ideas and thoughts in alternative ways and languages. It is clear that under some conditions, access to two languages can accelerate

[12] "Balanced" bilinguals refers to students who possess equal ability in both languages (Carringer, 1974)

aspects of cognitive growth. While these aspects show that their bilingualism may be an advantage for bilingual learners, research shows that not all levels of bilingualism are necessarily beneficial to learners and that bilingualism in and of itself does not translate into improved cognitive growth (Cummins, 1979). This has been argued from the point of view that there are two forms of bilingualism, as identified by Lambert (1981).

2.3.1.1 Two forms of bilingualism

The dominance and prestige (or not) of a home language influences the form of bilingualism that a learner attains. Lambert (1981), working with the notion of social value and worth associated with various languages, identified two forms of bilingualism; additive and subtractive. Additive bilingualism occurs in instances where, in learning a second language, a learner adds another language to his/her repertoire of languages. In other words, the first language is dominant and prestigious and in no danger of being replaced by the second language. An example in the Kenyan context is a student whose home language (and also dominant language) is Kiswahili and who is learning English. These two languages have a social value and worth at national level; Kiswahili is a national and official language, and is used to communicate with members of different language communities. While it is the dominant language for such a student, it is also prestigious at a national level. On the other hand, English is the official LoLT for all non-language subjects, and currently has greater social value and (economic) worth since it facilitates access to social goods such as higher education and employment. By learning English, this Kiswahili dominant student adds another socially valuable language to his language repertoire, hence this is additive bilingualism.

In contrast, subtractive bilingualism occurs if learning a more prestigious second language gradually replaces the first language. In this case, the bilingual's competence in his two languages at any point in time is likely to reflect some stage of subtraction of the first language and its replacement by the second language. The student reflects less than native-like competence in both languages. Again I cite an example from the Kenyan context. Learning and teaching in Standards one to three is in the home language of the students, with a gradual shift to English; for instance, where Dholuo is the LoLT and there is a gradual shift to use English in Standard four (Cleghorn et al., 1989). In the process of learning and using English as LoLT, Dholuo is replaced by English. After all, Dholuo is not used as LoLT or taught as a subject from Standard four onwards. This is in contrast to English which has more social value and worth in future schooling and in accessing social benefits such as employment. Thus Dholuo is academically subtracted from the learner's language repertoire and replaced by English.

2.3.1.2 The threshold hypothesis

Drawing on Lambert's (1981) work, Cummins (1979) suggested that there could be beneficial threshold levels of linguistic competence in both languages, which a bilingual child must attain in order to avoid cognitive deficits and allow cognitive growth. According to Cummins (1979), the level of competence in the main and second language that a bilingual student achieves acts as an intervening variable in mediating the effects of the bilingual learning experience on cognition in subject matter taught in a second language. In this regard, Cummins identified threshold levels of linguistic competence as: a higher threshold level that might be necessary to achieve accelerated cognitive growth, and a lower threshold level of bilingual competence that would be adequate in avoiding any negative cognitive effects. The core of this hypothesis was the maintenance and development of the home language as the student acquired competence in the second language.

In conclusion, it is clear that bilingualism does not necessarily disadvantage a bilingual learner, as early studies have tended to suggest; rather, there are advantages associated with it. Other research has shown that there are different forms and levels of bilingualism that are considered necessary for cognitive growth and linguistic development in a bilingual learner. In fact, it has been argued that bilingualism is not commensurate with cognitive and linguistic development. Questions have arisen as to whether bilingualism is particularly beneficial for bilingual mathematics learners and of how linguistic interdependence affects mathematical achievement in such learners. Researchers in mathematics education have analysed and discussed bilingual learners' mathematics achievement in relation to their two languages (see e.g. Clarkson & Galbraith, 1992) and in relation to the LoLT only (e.g. Mestre, 1981, 1988). In the section that follows, the effect that competence in either or both home language and LoLT has on bilingual students' performance in mathematics is discussed.

2.3.2 Influence of bilingual learners' language competence on mathematics performance

Research shows a range of influences that bilingual learners' language competence has on their mathematics performance. The language competence may be in either one or both languages in their language repertoire.

Bilingual students are disadvantaged in mathematics performance by language demands when the LoLT is not their home language (see for example, Mestre, 1981, 1988). In his study, Mestre (1988) observed that Hispanic-English bilingual undergraduates underperformed in algebra tests and word problems, with a significant difference in word problems. This performance was the result of language related interpretive demands and not necessarily because they were less proficient in mathematics. The bilinguals were also slower and less accurate than their monolingual peers (see also Clarkson, 1984; De Courcy & Burston, 2000; Stacey & MacGregor, 1991).

While proficiency in the LoLT, here English, was necessary in mediating the learning and interpretation of technical and symbolic language in word problems, Mestre (1988) observed that the bilinguals were less proficient in English than their monolingual peers. This lower proficiency consequently hindered the bilingual students' learning and interpretative ability. Mestre concluded that the bilinguals had a language deficit. In my view, their poorer performance may not simply have been a case of language deficiency; it may have been a reflection of the fact that the Hispanics were still in the process of learning the LoLT, which was not their home language.

While studies by Mestre (1981, 1988) are useful, the findings are limited because for many bilinguals the LoLT is a language in which they are still developing proficiency, while they are also using it to learn mathematics. Furthermore, these findings do not take into account the bilinguals' competence or fluency in their home language.

Considering bilingual learners' mathematics performance in relation to their proficiency in both LoLT and home language could provide more insights into understanding their mathematics achievement (see for example, Clarkson, 1992). This is because they use languages in their repertoire in ways that are different to the way in which monolinguals use their single language. Grosjean (1982, 1985) proposed what he referred to as a holistic view of the bilingual; a bilingual has a unique and specific linguistic configuration, that of a fully competent speaker-hearer who has developed competencies to the extent required by his/her needs. He/she may use the two languages separately or together for different purposes (1985, p. 471). Using Grosjean's notion of a bilingual person, considering a bilingual learner's competence in his/her two languages could be more informative of his/her mathematics achievement. In the section that follows, I draw on findings that have evaluated bilingual learners' mathematical performance in the light of competence in both their languages.

Research shows that bilingual learners who succeed in mathematics are those who are highly competent in both the home language and the LoLT (see, for example, Clarkson, 1992; Clarkson and Galbraith, 1992; Dawe, 1983; Farrel, 2011; Ni Riordain and O'Donoghue, 2009). Based on cognitive theories and Cummins' (1979) threshold hypothesis in particular, these studies show that bilingual learners' competence in both their home language and the LoLT can be an advantage in mathematics achievement, while less than native-like competence in one or both languages results in lower mathematical achievement.

Dawe (1983), for instance, argues that mathematics reasoning in a deductive sense is closely related to the ability to use language as a tool for thinking. In the case of bilingual learners, this ability involves competence in both languages. Dawe worked among bilingual Punjabi, Mirpuri, Italian and Jamaican 11 to 14-year-olds who were learning in English as a second language. He found that first language competence was an important factor in the learners' ability to reason deductively in a mathematics test that was presented in English. In particular, the ability of learners to make effective use of the cognitive functions of their first languages was a good predictor of their ability to reason deductively in English. Furthermore, the abstraction level of the first language was important for mastering conceptual operations connected with mathematics. Dawe concluded that first language maintenance is important for bilingual learners as a means of reasoning deductively in mathematics tests in their second language. If bilingual learners are to use their two languages as proposed by Dawe, they need to be competent in both languages. While Dawe noted that his findings supported the threshold hypothesis, these findings suggest that learners gain competence in both languages through additive bilingualism.

Clarkson and Galbraith (1992) argued that students who are more competent in both home language and English have higher levels of achievement in mathematics, and students who are less competent in either or both languages, and their English monolingual peers, have lower levels of achievement in mathematics. Clarkson and Galbraith (1992) worked with Grade 6 bilingual students in urban schools in Papua New Guinea. Melanesian Pidgin was the most common language of general communication and English was the LoLT. Students who were highly competent in language displayed greater competence in all types of mathematics questions than their less competent peers. These findings suggested that the bilinguals' levels of competence in their home language and in English had a significant influence on their performance in mathematics. Thus the findings gave some support to Cummins' threshold hypothesis. The authors then suggested that bilingual students who were competent in both languages could be more flexible in dealing with diverse question forms in general mathematics, at least in the test that had been used. Clarkson and Galbraith (1992) also suggested that bilingualism should not be considered as unidimensional but rather as multidimensional in all bilingual learning situations (see also Clarkson, 1992). In other words, the level of competence in each language that a bilingual student exhibits is a vital factor that needs to be considered in all bilingual learning situations.

While the findings of Dawe (1983) and Clarkson and Galbraith (1992) give support to the threshold hypothesis, it is interesting to note that conversational proficiency in the LoLT and the home language are not sufficient in ensuring mathematical achievement (Gerber, Engelbrecht, Harding, & Rogan, 2005; Gorgorio & Planas, 2001); rather, competence in all major language skills, that is, writing, reading, and speaking, listening and thinking is required. In fact, Pimm (1987) argues that students should learn to speak, listen, read and write like mathematicians as discussed in section 2.2 above.

The studies discussed in the preceding sections have provided important insights into linguistic interdependence in general; competence in a second language is partly a function of competence in the first language. This interdependence has led to explanations of why bilingual learners should maintain their home languages as they develop the second language, particularly as they learn mathematics. They have also provided important comparisons between bilingual and monolingual learners' performance in mathematics in relation to language competence. As such, when considering a bilingual learners' mathematical competence, the two languages in his/her repertoire and the level of competence in both should be taken into account. This leads one to ponder the influence of trilingual students' language competence on their mathematics achievement.

While the tasks given to the students in the studies discussed in this section were expressed in the LoLT, the findings encourage bilingualism and are thus in many ways at odds with studies that have positioned bilingualism as a hindrance. These studies are framed by cognitive theories and focus thus on the competence of a student in his/her two languages as the main determining factor of a bilingual student's mathematical competence. However, these studies do not reveal how competence in these languages can be used to support learning and teaching in bilingual contexts.

In the section that follows, I discuss studies that have focused on whether (and if so, how) competence and the language asset embedded in the bilinguals' two languages assists students in making sense of mathematics in tests, and in learning and teaching situations. In my view, insights into how students use their languages in mathematics engagement are partly embedded in how they perform when presented with mathematics tests in either of the two languages.

2.3.3 Mathematics tasks in two languages: insights into performance

Research has revealed contrasting yet enriching findings in situations where bilingual students are presented with mathematics tasks in their home languages and the LoLT. Bilingual mathematics students perform better in mathematics when tests are presented in their home languages rather than in the LoLT (De Courcy & Burston, 2000; Ni Riordain & O'Donoghue, 2009, 2011; Zepp, 1982). For example, De Courcy and Burston (2000) found that English-French bilingual learners in Australia had difficulties in understanding and interpreting some words and phrases in French, which was the LoLT, compared to their peers who did the same test in English. Beside the fact that French was not the home language of any of the learners, it was not taught as a subject. This made comprehension even more difficult for this particular group of learners. As a result, lack of comprehension and subsequent interpretation was the key point that led to students' lowered performance in mathematics. It was further noted that these students took longer to read and complete test items in French than their peers who read in English. De Courcy and Burston (2000) therefore hypothesised that if these learners were given more time in the test they would have formed a better understanding and could consequently have fared as well as their peers. Thus the use of French, in which the learners were still developing proficiency, negatively affected their mathematics performance, while the English first language speakers who did the test in English performed better.

In contrast, some research has shown that bilingual English second language students perform better in mathematics tests presented in English than when they are presented in their home languages (Llabre & Cuevas, 1983; Ni Riordain & O'Donoghue, 2009, 2011; Zepp, 1982). For instance, Zepp (1982) found that bilingual Form four students in Lesotho performed better in an English test of logical connectives than their peers who did the test in Sesotho. As English was the LoLT in secondary school, the Sesotho Form four students seemed to have learnt English sufficiently well to use it to think logically, hence their better performance in the test presented in English. It was also noted that a few of the students who did the Sesotho version of the test wrote their responses in English. Zepp argued that this showed that the students thought through the tasks in English. He concluded that although instruction in English facilitated logical thinking in English, the knowledge acquired in English did not seem to transfer readily to thought in the first language, and hence the better performance in the English than in the Sesotho version of the test.

This discussion of bilingual assessment does not give particular weight to assessment either through the LoLT or in the home language. The studies discussed above engaged different groups of bilingual students in tests in one of their languages, with varying results. What the findings do not tell us is whether and how the two languages can support bilingual students in their participation in the mathematics classroom and improve their mathematics performance as they gain proficiency in the LoLT, which in most cases is not their home language.

2.4 Conclusion

In this chapter, I have discussed research on the relationship between language and mathematics, and language diversity and mathematics education. I have shown that language and mathematics are intricately related, with the mathematics language borrowing and using words from ordinary English. These words often have very different meanings in the two languages and this can cause confusion. In the discussion on formal and informal mathematical languages, I highlighted the fact that students need to use their informal language and ways of knowing in order to learn the formal language of mathematics that is important in school mathematics.

This chapter also highlighted the fact that studies on mathematics education and language diversity can be traced back to studies on bilingualism and bilingual students. The development of research in this area has shifted the focus from the negative effects of bilingualism to its positive effects and from language competence to home languages as resources in mathematical performance. I have shown that when considering a bilingual student's mathematical competence, the two languages in his/her repertoire and the level of competence in each should be taken into account. I have shown, too, that when both a bilingual student's languages are used in mathematics assessment, the results do not point to the superiority of assessment in either of these languages. While these findings provide some insights into bilingual students' mathematics performance in relation to their two languages, they do not tell us whether and how bilingual students themselves use their two languages as resources when solving mathematical problems. The "whether" and "how" of using these languages have not only been explored in the bilingual context but also in multilingual contexts. The need to review these two aspects necessitates the inclusion in this study of the aspect of language practices among bilingual and multilingual students. This area of language practice has been researched in mathematics education, as discussed in the next chapter. However, no studies on language practices among trilingual students have been reported; for this reason, this is the focus of the present study.

CHAPTER 3

LANGUAGE PRACTICES OF BILINGUAL AND MULTILINGUAL MATHEMATICS STUDENTS

3.1 Introduction

Understanding the language practices of bilingual and multilingual mathematics students can shed light on the language practices of trilingual students of mathematics. This understanding is also important in order to figure out why it is necessary to focus specifically on trilingualism. As discussed in Chapter 1, section 1.2, research on mathematics and language diversity has focused mainly on language practices among bilingual and multilingual students and not on trilingual students. In Chapter 2, section 2.3.3, I discussed bilingual students' performance when different groups were presented with tasks in two languages. This resulted in a balanced performance that did not point to the superiority of either the LoLT or the home language in this regard. While acknowledging that assessment in two languages is one way in which research can explore how bilingual students' use languages, the findings do not tell us much about the language practices of these students.

The study reported in this thesis explored the language practices of some trilingual students in Kenya and investigated how they drew on their language resources to make sense of mathematics. In order to understand language practices in other linguistic contexts the following are discussed in this chapter:

- Language practices of multilingual learners when presented with tasks in two languages
- Code switching as a language practice among bilingual and multilingual students. The elaborate discussion of code switching was necessitated by the fact that it is the most common language practice reported among bi/multilinguals in the learning and teaching environment. This could imply that code switching is also a

practice among trilingual students.

- Finally, how trilingual learners have used their languages in studies in linguistics is discussed. This discussion is intended to prepare the ground for the investigation into trilingual mathematics students' use of their languages.

Research has shown that both the LoLT and learners' home languages are used as learning and teaching resources (see e.g. Adler, 1998; Planas & Setati, 2009). However, the language of assessment has been limited to the LoLT. The debate on assessing learners in more than one language continues, especially in South Africa (for examples see Heugh, 2009; Setati, 2005). It is not surprising, then, that research on how multilingual learners of mathematics use their home languages and LoLT when engaging in mathematics tasks presented in both languages has been conducted in South Africa.

3.2 Language practices of multilingual students

With the aim of exploring how multilingual learners use the LoLT and their respective home languages during mathematics lessons, a team of researchers (Nkambule, Setati & Duma, 2010; Setati & Duma, 2009; Setati, Molefe & Langa, 2008) in South Africa introduced what they referred to as the deliberate, strategic and proactive use of the learners' home languages during mathematics teaching and learning, presenting mathematics tasks in multiple languages. Each learner was given the task in two languages, the LoLT (English) and their home language. The experiment was conducted in various Grade 11 multilingual classrooms where learners were presented with a real life mathematics task. The learners were grouped according to their respective home languages and encouraged to communicate in any language at any stage during the lesson as they worked on the task. Lesson observations and analysis of the students' interactions revealed that the learners were code switching between the LoLT and the home languages to explain their reasoning, to raise arguments and to negotiate meanings. Nkambule et al. (2010) and Setati et al. (2009, 2008) argued that, during the lesson, learners had an opportunity to draw on multiple languages without the constraints of having to ask for permission from the teacher. Using both English and their respective home languages as resources for communicating their understanding and raising arguments, the learners participated in the mathematics lesson. Furthermore, Setati et al. (2008) argued that the success of the strategy lay not only in the use of multiple languages but also in the nature of tasks.

The discussion above has introduced the notion of code switching in multilingual mathematics contexts. In the case above, code switching provided insights into how multilingual learners are able to use the languages at their disposal to participate in learning. Other studies in bi/multilingual classrooms have shown that code switching between students' home languages and LoLT can support not only their participation in the mathematics classroom but also their performance in mathematics. In the next section I discuss studies that have investigated how and why bi/multilingual learners switch to their home languages when they engage with mathematics tasks that are presented in the LoLT. Hoffmann (2001) notes that bilingual and trilingual speakers use language at their disposal in more or less the same ways. Therefore the findings on language practices of bi/multilingual students will inform and provide insights into the language practices of trilingual learners.

3.3 Code switching

Code switching is the alternative use of two or more languages in an utterance or conversation in a more or less deliberate way (Baker, 1993; Grosjean, 1982). The alternation can involve a word, a phrase, a segment of a sentence, a sentence or several sentences. It is a common characteristic of bi/multilingual speech and there are communicative purposes for which it is used. While the works of Baker and Grosjean portray code switching as a verbal strategy, a corresponding non-verbal strategy of language switching has been proposed and used in research on mathematics education.

Language switching refers to the use of two or more languages during solitary and/or mental arithmetic computation (Moschkovich, 2005). Moschkovich views the difference between code switching and language switching as that of using two languages during conversations or during solitary and/or mental arithmetic computations. The use of two languages during mental arithmetic computations involves switching between two languages when thinking through computations. While I support this differentiation, I note that linguists use the terms code and language differently.

In linguistics, the term code is synonymous with language or speech variety (Jakobson, Fant & Halle 1952 in Ogechi, 2002). According to Jakobson et al. (1952 in Ogechi, 2002), code is preferred to language or dialect because of the problem of clearly delimiting language and dialect. Therefore, code is used as a general term for language, dialect and other related terms. In this study, I do not differentiate between languages and dialects used by the students; I choose to refer to all situations where students switch between languages in verbal conversations or in mental computations as code switching. This applies to all situations where switching occurs: in bilingual, multilingual or trilingual students. However, the differences between the language skills in conversation and mental computations or thinking will be noted where appropriate.

Code switching can only occur within an individual user or among users of more than one language; it is then both an individual and a societal language practice. While it may be used by people who are proficient in the given languages, in classroom situations it is more commonly used because learners are still developing proficiency in the LoLT. It more often involves switching from the LoLT to the learner’s home language. In a single speech, code switching may serve different purposes in the communication and the languages involved may have a range of functions.

Code switching happens for a range of purposes; to translate content from one language to another, to easily and efficiently express oneself, to express group identity and status, and in response to the context of using language (Baker, 1993; Cohen, 1995; Grosjean, 1982; Kern, 1994). As observed by Baker (1993), these purposes show that code switching has linguistic properties as well as social and power aspects. These reasons are complexly interwoven when people switch between languages. It should be noted, however, that the availability of more than one language does not necessitate code switching. Furthermore, code switching is not a straightforward matter; there are different views associated with it.

There are various functions to which people may put their language(s) (Halliday, 1973; Halliday & Hasan, 1989). Some of these include representational, social interaction, personal expression, heuristic, and imaginative functions. These functions depend on their adequacy in meeting the needs of the speaker. They show that language serves to communicate with one-self and with others. Although Halliday (1973) discusses these functions from a child's perspective, some of them feature when code switching occurs among adults. The different functions of language therefore suggest that the different languages used in code switching may have the same or different communicative functions.

There are, however, different views regarding code switching. It has been argued that those involved in extensive code switching know neither language well enough to converse in either and are considered to be "semilingual" or "nonlingual" (Grosjean, 1982). One consequence of this negative attitude is that some bilinguals never switch, while many others restrict their switching to situations in which they will not be stigmatised for doing so (see e.g. Grosjean, 1982). Despite these attitudes, code switching fills a momentary linguistic need and is a useful communication resource in the learning and teaching of mathematics.

Code switching is a common phenomenon in mathematics classroom situations where different languages are represented. In some bi/multilingual classrooms it is the norm rather than the exception and it is used deliberately in a proactive and/or reactive way. In what follows I discuss the purposes for which code switching has been used, particularly in bi/multilingual mathematics classrooms, and its influence on the learning and teaching process. In so doing, the process and reasons for code switching are discussed.

3.3.1 Purposes of code switching in bilingual and multilingual mathematics classrooms

Research shows that code switching between learners' home language and the LoLT supports learning and teaching in bi/multilingual classrooms (Chitera, 2009a, 2009b; Clarkson, 1996, 2003, 2005, 2006; Cleghorn et al., 1989; Dominguez, 2011; Kazima, 2006; Khisty & Chval, 2002; Khisty, McLeod, & Bertilson, 1990; Merritt et al., 1992; Moschkovich, 2005; Ndayipfukamiye, 1994; Parvanehnezhad & Clarkson, 2008; Planas, 2011; Planas & Civil, 2008; Planas & Civil, 2010; Planas & Setati, 2009; Setati, 1998,; Setati & Adler, 2000, Setati et al., 2002, Setati et al., 2008). In some contexts, code switching is a preserve of the teachers (for example in Botswana, see Arthur, 1994), while in others it is a common language practice for both teachers and learners (for example in South Africa, see Setati, 1998).

Whenever it is used in the learning and teaching of mathematics, code switching has a range of purposes. Some of these purposes are discussed below with the functions of the language(s) used embedded in the communicative process. Furthermore, most of the studies that focus on code switching have been conducted with learners who were still learning the LoLT and had limited ability in it. Exceptions to these are the studies of Clarkson (2006) and Parvanehnezh and Clarkson, (2008), in which some learners had considerable proficiency in both the LoLT and their respective home languages. It has been observed that some bilingual learners reduce their code switching practices as they continue to learn the LoLT while others do not find it necessary to engage in code switching at all.

3.3.1.1 Translating from one language to another

Code switching with the purpose of translating from one language to another is practised for a range of linguistic reasons (Kern, 1994). According to Kern, translation is the expression of a message in a language other than the one in which it was originally formulated. It can assume verbal, written and mental communication. Translation is only possible when the message is first understood in the original language. Working with 51 native English-speaking university students who were learning through the medium of French, Kern (1994) reported that some of these students made conscious efforts to mentally translate what they read in French into the more familiar language, English. Reasons for which translation has been used in mathematics (and to some extent in science) classrooms include familiarity with the other language(s), emphasis of a point or simply a constant practice, as discussed in the following section.

a. ***To express words or phrases in the language that is more familiar than the other***

According to Kern (1994), thinking in the home language converts input into more familiar, more accessible terms, enhancing learners' confidence in their ability to comprehend this input. It has been observed that bilingual mathematics students translate mathematics task content because of their familiarity with certain words and numbers in their home language, and not because of a lack of knowledge of these words (Moschkovich, 2005; Parvanehnezh & Clarkson, 2008). For instance, according to Parvanehnezh and Clarkson, (2008), bilingual students' translation can be understood as resulting from habitual use of the words in the particular language. These words are used even when they are less formal. Parvanehnezh and Clarkson, (2008) observed that, when presented with certain words in English, Persian bilingual learners read them in Persian. For instance, the word 'girl' was read in Persian as 'dokhtar'. While the task was difficult, the code switching was not associated with this difficulty but with the learners' habitual use of the word 'dokhtar' in Persian. Parvanehnezh and Clarkson, (2008) argued that the language switching in this case was not for the sake of seeking cognitive engagement with the task, but rather from habit.

Studies in multilingual settings have found that teachers commonly switch from the LoLT to their learners' home languages to make lesson content more familiar to them (Cleghorn et al., 1989; Setati, 1998,). Cleghorn et al. (1989) report that a Standard Eight teacher in Kenya used local words in Dholuo that were used in daily activities to render the content of the lesson more familiar. The local words such as 'matumbo', 'sufuria' and 'shamba' are Kiswahili words that have been incorporated into the Dholuo language. Cleghorn et al. (1989) observed that the use of local and familiar words may have expanded students' awareness of word meaning and language differences, helping to develop their English competence while also fostering understanding of the concepts being taught. This was necessary as the students were still developing proficiency in English while they learnt science in this language. This discussion of students' familiarity with their home language is pertinent to trilingual students in Kenya.

b. ***To emphasise a point or certain words***

Translation may also be used to emphasise a point or words or phrases (Baker, 1993; Merritt et al., 1992). In this case, words are substituted with words from another language for emphasis; however, no explanations are provided for these words (Merritt et al., 1992). For instance, in their study, Merritt et al. (1992) found that while speaking of a container, a Standard Eight teacher used the word 'mkebe', the Kiswahili equivalent for 'container'; similarly, for tapeworm, he used 'jofi', the Dholuo word for tapeworm. In so doing the teacher emphasised specific objects without explaining their meanings.

Kern (1994) observes that when mental translation is on a word-for-word basis, it may not provide integration of meaning; rather, it helps to fix the words more solidly in the memory. A concern for this study is whether translation of some English words to home languages was a practice among the trilingual students.

c. ***Constant translation***

Some students translate text constantly. Kern (1994) observed that students transformed visual information presented on a page in French into a mental representation of an English text that could be more easily processed. The ultimate goal was to transform information into a more usable representation.

In Clarkson's (2006) study, Vietnamese mathematics students translated problems from English into Vietnamese. The use of Vietnamese was associated with the assistance the students received from their parents who used mainly Vietnamese or from siblings who used both English and Vietnamese. Consequently, while at school, the students translated problems into Vietnamese while reading and thinking them through. They then translated them back into English to make the ideas compatible with the classroom language situation. While it is not clear whether the students in Clarkson's study translated all the content, he noted that they did not translate individual words to check for meaning. Translation of all content may, however, pose a challenge since some of the terms in mathematics may not be available in home languages or may not be readily used (Setati, 1998). Furthermore, translation does not always work to the advantage of students (Kern, 1994); if content is inaccurately translated it may lead to misconceptions. A relevant question here is "do trilingual students constantly translate tasks provided in the LoLT? If so when and why? What implications do the translations have on their engagement with the task?"

Most studies reviewed here, focusing on the use of code switching for translation purposes, were conducted with learners in the early or middle stages of learning their LoLT. At this point of learning their LoLT, which was not their home language, some reliance on their home languages in the form of mental translation was probably inevitable. In contrast, all the students in the study described in this thesis were academically proficient in the LoLT, despite the fact that it is imperative to find out how translation plays out while they engage with mathematics tasks.

3.3.1.2 Ease and efficiency of expression

Some bilingual students switch between languages in order to express themselves easily and efficiently (Planas, 2011). The students make personal decisions to switch between their languages. These decisions are not necessarily the result of their not knowing a word or a phrase in one language; rather, they are taken to facilitate the use of words or phrases in the other language. For instance, some Vietnamese bilingual students switched from English to Vietnamese simply because it seemed easier to do some parts of a task, like fractions, in Vietnamese (Clarkson, 2003, 2005, 2006; Parvanehnezh & Clarkson 2008). A relevant concern for this study is whether trilingual students may find it easier and more efficient to complete some parts of a mathematics problem in a different language than the one in which it was presented. If so, it raises the question of whether switching is associated with the problem involved or the means of communicating the mathematics.

3.3.1.3 To express identity

Code switching is used to mark and emphasise group identity (Cohen, 1995; Grosjean, 1982). Identity may be marked by varying degrees of speakers' involvement in any communication. For instance, a home language may be used to convey personal involvement while the other language is used to mark more general or detached statements (Cohen, 1995; Gumperz, 1970 in Grosjean 1982). Gumperz (1976, in Grosjean, 1982) generalises this interpretation to other code switching situations where the majority language[13], which he refers to as the "they code" is associated with more formal, stiffer, less personal out-group relations, whereas the minority language[14], the "we code", is associated with in-group and informal activities and identities. These observations are consistent with the way formal and informal mathematics languages are

[13] Majority language here refers to a language that is used as a home language by the majority of speakers in a given context.
[14] Minority language here refers to a language that is used as a first/home language by a few speakers and is not the home language of the majority of speakers in a given context.

used by students; formal mathematics language is associated with school mathematics while the latter is the kind of language associated with everyday life to express their mathematical understanding (see section 2.2.1). Furthermore, it is consistent with Gee's view that Discourse is about identity; presenting oneself as a particular individual who engages in a particular kind of activity (1999, 2005). Gee's view is used in the analysis of this study and is discussed in detail in Chapter 4. Thus switching between a home language and other languages may show how learners identify themselves or are identified by others, as individuals or as groups of learners.

In a bilingual mathematics classroom, Spanish-Catalan students exhibited hybrid language identities based on the use of the two languages (Planas, 2011). These identities were negotiated and also resisted in relation to social, cultural and academic settings. The use of the two languages in the class opened up various identity options; for instance, a personal or collective initiative to use both or either of the languages. The options were motivated by the need to accommodate other learners, especially those who were not Catalan first language speakers who were referred to as "other" learners, and languages used at home. For instance, a Catalan first language speaker found it easier to use Spanish if the group included "other" learners. Here the learner identified himself with the use of the two languages and marked the Spanish-dominant language student identity as one who could understand Spanish better than Catalan. Language identity was also marked by the use of the language in which mathematics was presented as well as that of the textbooks, hence privileging Catalan over Spanish for academic reasons.

It is clear from the students' language identities that Catalan and Spanish were privileged differently in the bilingual mathematics classroom. Drawing on Gumperz (1970 in Grosjean 1982), we could argue that Catalan functioned as the "they code" while Spanish functioned as the "we code".

In multilingual contexts, code switching to a minority language is seen as a signal of solidarity. Chitera (2009b) observed that the use of minority languages as a “we code” was upheld in a college mathematics pre-service teacher education classroom, signalling group solidarity. Chitera reports that multilingual student-teachers who could not express themselves in the LoLT, English, or in the national language, Chichewa, were allowed to express themselves in their home language, Chitumbuka, which was a minority language in this particular context. In so doing, the educators and the Chitumbuka student-teachers built intimate interpersonal relationships among themselves in the classroom. This relationship indicated group membership and personal connections, hence signalling the solidarity of an in-group within the classroom.

Expressing ones’ identity by switching between languages has been used in bilingual and multilingual contexts. Identities that trilingual students enact when they switch languages are explored in this study; the study investigates whether or not such students make personal initiatives to switch in order to express certain identities, and whether or not their languages can be identified as “we codes” and/or “they codes”. The aspects associated with code switching and how the identities were negotiated, were also considered.

It is not only through an analysis of the languages used (e.g. English and Kiswahili) that we can understand students’ identities; an exploration of the various linguistic elements of language(s) in use can also reveal the identities involved. Pronouns, for instance, express and shape our identities in specific contexts. The use of pronouns is most relevant to the theoretical framework in Chapter 4 (section 4.3.1.1) and will be discussed there.

3.3.1.4 Context of using language

Research has shown that the context in which bi/multilingual learners find themselves may facilitate or constrain code switching (Cohen, 1995; Grosjean, 1982). Contexts involve both physical environment and the presence or absence of other people. For instance, memories about people or situations in which other languages were used trigger switching (Cohen, 1995). Further, as noted earlier in this section, in contexts where extensive code switching is viewed as an inability to converse in either language, most learners restrict their switching to situations where this will not be stigmatised (Grosjean, 1982). In contrast, learners switch freely between languages in situations where they do not feel intimidated.

Research in mathematics classrooms provides evidence of the influence of context in language use (Clarkson, 2006; Parvanehnezh & Clarkson, 2008; Planas & Setati, 2009). For instance, bilingual learners switch between their home language and the LoLT while operating in their individual private world or in small groups (Clarkson, 2006; Planas & Setati, 2009). Switching in small groups is likely to be facilitated by the fact that the learners share a home language. In contrast, bilingual learners use the LoLT when they are organised in linguistically mixed groups (Planas & Civil, 2008) and when they share mathematical ideas with a class whose members do not share a home language (Planas & Setati, 2009). According to Planas and Setati (2009), students may keep to the LoLT when they know they are being watched by their monolingual peers. These authors reported that the students in their study continued to use the LoLT despite being prompted to use their home languages, probably viewing their home language as a language that was not valued in mathematics classroom learning. This constraint on code switching may be more pronounced in environments where learners are restricted by the teacher from using languages other than the LoLT (Arthur, 1996), and to a larger extent by the LiEP.

Furthermore, the physical environment in which bilingual learners work and the languages that researchers use to interact with them can also facilitate or constrain code switching. For example, the Persian language school in which Iranian learners were interviewed triggered their memories, causing them to remember events or customs associated with Persian, which was the norm in the school (Parvanehnezh & Clarkson, 2008). Their memories were linked to the context of the problem. These memories then prompted learners to switch from English to Persian.

Given that code switching may be prompted by contexts, it is important to identify and understand those contexts that facilitate or constrain trilingual undergraduate students' switching between languages when they engage with mathematics tasks.

3.3.2 When code switching is not used

It has been observed that code switching is not practised by some mathematics students (Clarkson, 2006; Moschkovich, 1996; Parvanehnezh & Clarkson, 2008). A range of reasons have been suggested for this. In the studies by Clarkson (2006) and Parvanehnezh and Clarkson (2008), for instance, some students simply did their mathematics in the LoLT without finding the need to switch to their home languages. In her work, Moschkovich (1996) describes situations in which bilingual students had been exposed to mathematics in the LoLT only and hence talked about mathematics in the language in which it was taught without switching to their first languages. The fact that mathematics learning and application of formulae is predominantly expressed in the LoLT made some Kirundi first language speakers in Burundi keep to French rather than switching to Kirundi (Ndayipfukamiye, 1994). These findings suggest that having two languages in their repertoire do not guarantee that bilingual students will switch between languages. While no research findings in multilingual contexts report on this phenomenon, Merritt et al. (1992) noted that one university lecturer in linguistics and native speaker of Kikuyu was initially reluctant to translate a passage on the water cycle because, according to him, the notion was not talked about in Kikuyu. In the study reported in this thesis, it was necessary to find out whether trilingual students kept to the LoLT.

The literature on the purpose of code switching reviewed above raises some pertinent concerns for researchers who study code switching; these also have a bearing on the study reported here. For instance, code switching can occur as a result of the habitual use of words and phrases and not because of the perceived difficulty of the subject (see

Parvanehnezh & Clarkson, 2008). The challenge is thus to understand how difficult a task has to be for students to switch languages in order to engage cognitively with the task, and also to determine when students switch because of their habitual use of certain words. It is also clear that while learners switch to their home languages to express unknown or unfamiliar terms (Moschkovich, 2002), others keep to the LoLT when becoming familiar with new words (Planas & Setati, 2009). These aspects highlight the fact that code switching is not a straightforward matter.

I have discussed language practices among bi/multilingual students. The language practice of code switching has been found to support bi/multilingual students' participation and performance in mathematics. While these findings on mathematics education in bilingual and multilingual contexts are useful in helping us to understand the relationship between language and mathematics education, they do not explain the language practices of trilingual students, particularly at undergraduate level.

3.4 How trilingual students use their three languages

Hoffmann (2001) points out that from a language learning perspective, switching between languages is an important speech strategy for trilingual speakers. Consistent with Grosjean's holistic view of a bilingual speaker (1982, 1985), Hoffmann (2001) observes that trilinguals are competent speaker-hearers within their linguistic environment and communication requirements. Furthermore, trilinguals never use all three languages simultaneously, nor do these languages have equal importance for them. According to Hoffmann (2001), trilinguals assign, consciously or otherwise, different functions to their three languages. Once the dominant language has emerged, depending on the situation, they switch between the dominant language and one of the others. The dominant language is employed more frequently and in a wider variety of domains and functions than the other two languages. In practice, trilinguals have a tendency to behave like bilinguals (Clyne, 1997, in Hoffmann, 2001). For example, in education the LoLT is more commonly used in external communication, but the home language is used more often as a language of inner functioning. While Hoffmann attempts to describe trilinguals, one aspect that could add weight to her description is an investigation into language practices of trilingual students while working on mathematics tasks. This is the focus of this study; it explores whether, how and why some trilingual undergraduate students use languages to make sense of mathematics. This study will thus enrich the discussion on mathematics education and language diversity from bilingualism to multilingualism, with a special focus on trilingualism.

In the next chapter, the theoretical framework that was used to analyse and explain the language practices of some trilingual mathematics undergraduate students in a university in Kenya is discussed.

CHAPTER 4

THEORETICAL FRAMEWORK FOR EXPLORING LANGUAGE PRACTICES OF TRILINGUAL STUDENTS

4.1 Introduction

This study investigated language practices of some trilingual undergraduate mathematics students in Kenya. The previous two chapters presented a review of research on the relationship between language and mathematics, and the role that language plays in mathematics students' performance, as well as the language practices of bilingual and multilingual students. This review highlighted the importance of focusing on trilingual students for mathematics education research and further showed that trilinguals have specific ways of using their three languages. It is therefore important to explore whether, how and why some trilingual mathematics learners draw on their languages when engaging with mathematics tasks. In order to do so, in this chapter I explain how I developed the theoretical framework that informed this study.

The study was broadly informed by Vygotsky's theory that development occurs in and through socially mediated activity and that language plays a key role in this mediation (Vygotsky, 1986; 1978). According to Vygotsky's theory, language serves first a regulative, communicative function and later becomes a tool for thinking. Language therefore has the power to transform the way people learn, think and understand. Central to Vygotsky's theory is the importance of social interaction in the formation of higher mental functions (Vygotsky, 1978, 1991). As he argued, any function in the child's cultural development appears first on the social plane (i.e. among people) and then on the psychological plane (i.e. within the individual).

Language therefore mediates both social interaction and individual thinking processes. As Mercer, (1995: 4) aptly puts it, language is a means for transforming experiences into cultural knowledge and understanding, hence its importance in mathematics learning and teaching.

While Vygotsky's theory is useful in understanding the role of language in trilingual students' engagement with mathematics tasks, it does not provide us with a methodology to analyse whether, how or why some trilingual students draw on their languages to make sense of mathematics. This is why Gee's theory of Discourse analysis (2005, 2011a) became relevant to this study. What follows in this chapter is a discussion of the rationale for using this particular theory and later the method of discourse analysis in general, and how it was used in this study.

4.2 Why the choice of Discourse analysis?

In order to explore whether, how and why some trilingual undergraduate students in Kenya draw on their languages to make sense of mathematics I needed a theory that would help me to understand the students' language practices. The envisaged theory was one that could be used to analyse not only spoken and written language, but also language used in tandem with actions and gestures in moment-to-moment engagements with mathematics. A theory, in other words, that would help me to explain why language was used as it was, and that would consequently enable me to categorise different themes that emerged from the analysis. In my view, the aspects of such a theory resided in Discourse analysis (Gee, 2005, 2011a)[15]. While this analysis is not specifically applicable in the context of language in mathematics education, it illuminates how and why language is used as it is in the particular context of this study.

Gee's approach to Discourse analysis seeks to balance "talk about the mind, talk about social interaction and activities, and talk about the society and institutions" (2005: 6). Furthermore, the approach looks at language used in tandem with non-language "stuff", for instance ways of thinking and gesturing. Gee refers to this approach as Discourse (with an uppercase D) analysis, as stated in Chapter 2 (section 2.2.2). Gee argues that by using language together with non-language "stuff", we project ourselves and are

[15] The theoretical construct in this thesis is largely adapted from Gee (2005); other work by Gee (1996, 1999, 2011a, 2011b) has been used to support or add more information to what has been taken from Gee (2005).

recognised (and we recognise ourselves) as certain kinds of persons engaged in certain kinds of activities (2005). He observes that certain types of activities in which we engage and identities we enact constitute the nature and give existence to specific social groups; in turn, the socio-cultural groups shape certain types of activities and identities. The language practices that the trilingual students in this study used in verbal communication, writing and thinking in relation to their social, culturally defined experiences shaped the identities they enacted and the activities in which they were engaged.

Furthermore, in his work on Discourse analysis, Gee not only provides a theory but also a method for studying how language is recruited "on site'" that is, "language-in-use in the here and now, to enact specific social activities and social identities" (Gee, 2005: 1). Gee also provides tools of inquiry and strategies to apply them in analysing data. These tools include social languages, Discourses, situated meanings and Discourse models. The tools help us to ask questions about what he refers to as the "seven building tasks" (Gee, 2005: 11) that we build when we use language, and to understand how language is used as it is used. These tools can be flexibly adapted to specific issues, problems and contexts of study.

Given these aspects, I found Gee's approach to Discourse analysis appropriate for an exploration of whether, how and why trilingual undergraduate students of mathematics drew on their three languages to engage with mathematics. Gee's work in Discourse analysis (1996, 1999, 2005) has also been used by other researchers in mathematics education to analyse language practices of bilingual and multilingual students (see for example Dhlamini, 2009; Moschkovich, 2002; Setati 2002, 2005).

For these reasons, I have adapted four tools of inquiry – social languages, Discourses, situated meanings and Discourse models – in order to ask certain questions about the building tasks in an attempt to understand language practices of trilingual students. These tools of inquiry allowed me to identify the different social identities and activities that students enacted as they interacted with a mathematical task, through their thinking, interpreting, and understanding, writing out and explaining the solution process. In the following section, I explain Discourse analysis, in particular the seven building tasks and the tools of inquiry that I used to analyse language practices of trilingual students.

4.3 Discourse Analysis

In explaining Discourse analysis, the seven building tasks are presented. It is also worth discussing, albeit briefly, the use of some pronouns which work together with building tasks as mentioned in Chapter 3 section 3.3.1.3. Thereafter, the tools of inquiry adapted for this study and the method of Discourse analysis are discussed.

4.3.1 The Seven Building Tasks

According to Gee (2005, 2011a, 2011b), we use spoken or written language in tandem with non-language "stuff" to perform actions in the world. Gee argues that the actions we accomplish using language allow us to build, rebuild, sustain or destroy things in the world over time, for instance social relations like friendship. Furthermore, in using language, we always and simultaneously build a world of activities and identities. We engage in at least one of the seven building tasks of language. We often do this in more or less routine ways, because of our cultural inclinations. Using knowledge of these building tasks, discourse analysts can ask questions about any piece of language-in-use connected to them. In the section below is a brief description of each building task and a statement of the discourse analysis question as provided by Gee (2005: 11–19).

1. **Significance**: we use language to make things significant. Certain words or phrases in our utterances mark the significance or otherwise of what we are saying. Thus we can ask:
   How is this piece of language being used to make certain things significant or not and in what ways?

2. **Activities**: we use language to be recognised or to recognise ourselves as engaging in certain sorts of activities here-and-now. What we say, do and are in using language enacts activities. At the same time, what we say, do and are would have no meaning unless these activities already existed. When activities are built, they are made in more or less similar ways in which they have been made before, by us and others, and that is why they are recognised. Thus the discourse analysis question is:

   What activity or activities is the piece of language used to enact?

3. **Identity**: we use language to be recognised as taking a certain identity or role here-and-now. In the different cultures, social groups and institutions of which we are members, we talk and act so as to be recognised as having the "right" or "appropriate" identity at the right times and places. Gee (2011b) cites the example of doctors; they talk and act differently to their patients when they are being doctors than when they are talking as acquaintances or friends, even in their offices. The same doctor can switch between the two identities at different points in an utterance or in different activities while engaging with the patient. For any piece of language, then, we can ask:

   What identity or identities is this piece of language being used to get others to recognise as operative?

4. **Relationships**: we use language to build and sustain social relationships with other people, groups or institutions with whom we are communicating. We relate to other people, social groups, cultures or institutions in terms of different identities we take them to have. In turn, the identity or identities we construct for ourselves are often defined, in part, by how we see and construe our relationships with others. For example, in a lecture room, a student may relate differently with a lecturer prior to a lecture session than during lecture time. In the first case, when learning and teaching are not taking place, the relationship may be informal, probably involving talking and acting as friends. During the lecture, however, the

two talk and act formally, portraying a lecturer-student relationship. Here we can ask:

What sort of relationship or relationships is this piece of language seeking to enact with others?

5. **Politics**: the term politics here means any situation where the distribution of social goods is at stake. Social goods here refer to anything a social group or society takes as good or worth having, for instance knowledge and employment (Gee, 2005, 2011a). We use language to convey or build a perspective of the nature of the distribution of social goods and how we think social goods are or should be distributed in the society, or among social and cultural groups. The discourse analysis question is:

   What perspectives on social goods is this piece of language communicating?

6. **Connections**: we use language to render certain things connected or otherwise to other things or to disconnect those that are connected. Sometimes the connections made are explicit, at other times implicit. Gee (2011b) cites an example of a king and a queen, and their death: "If I say 'the king died and then the queen died from grief' or 'the queen died because the king died', I make the connection of their deaths explicit" (2011b: 126). We can ask:

   How does this piece of language connect or disconnect things or ignore connections between things; how does it make one thing relevant or irrelevant?

7. **Sign systems and knowledge**: we use language to make certain sign systems (communication systems) and certain forms of knowledge (ways of knowing the world) relevant or privileged, or not, in given situations. We also contest different ways of knowing the world (Gee, 2005, 2011a). Sign systems include different national languages (e.g. Kiswahili and English), different varieties of any one language (everyday language, language of mathematics) and different communicative systems that are not language (e.g. equations, graphs, images). Different sign systems represent different views of knowledge and beliefs,

different ways of knowing the world. For example, I can talk and act in such a way that I make the knowledge and language of mathematics more relevant than everyday language while shopping in a mall. In other words, I look at some knowledge claim using a mathematics view where I could have used everyday language. The discourse analysis question that we can ask here is:

How does this piece of language privilege or disprivilege specific sign systems or different ways of knowing and believing or claims to knowledge and belief?

Gee (2005) notes that these building tasks are integrally linked to each other. For instance, sign systems and knowledge are linked to politics, while activity, identity and relationship building tasks are linked. These relationships may partly explain why we continuously and actively build and rebuild the building tasks simultaneously through the same or similar words, phrases and deeds in the here-and-now. However, in any use of language, some building tasks are more manifest than others.

Other than the identity and relationship building tasks, pronouns can help us to recognise the identity and activities that a speaker is enacting. Pronouns code and convey aspects of speakers' personal identity and group association (Rowland, 1999). The commonly used pronouns in mathematics talk are "I", "you" and "we" (Pimm 1987; Rowland, 1999). Drawing on the works of these authors, a brief discussion on the use of these pronouns in mathematics talk is provided in the next section with the aim of shedding light on how these three pronouns are used as identity and relationship markers.

4.3.1.1 Using "you", "I" and "we" in mathematics talk

Rowland (1999) observes that the use of "you" is based on some presumed shared experience between interlocutors. He argues that it may be used to refer to the speaker or the immediate person involved in the conversation, or to anyone. Thus "you" may be used in a generalised sense. "I" is used as a marker of personal action in time and space (Rowland, 1999). A speaker may shift from "I" to the impersonal "you" to detach him/herself from the conversation and thus give space to some generalisation in the mathematical discourse or relationship. However, it is also possible that "you" is sometimes used vaguely and it therefore becomes unclear as to who is meant to be included by it; the only certain person by implication is the speaker himself/herself (Rowland, 1999).

In a teaching situation, teachers and students use the pronoun "we" to appeal to different communities (Pimm, 1987). Pimm observes that teachers and students use it differently, in different contexts from the customary interpretation of a plural group, where the speaker is included. For instance, these uses include:

1. To elicit cooperation by implicitly involving the other in the activity. For instance, by referring to "we" in working out some mathematical task, the responsibility of working is spread to others who are not necessarily involved.
2. Mathematics textbooks and mathematicians traditionally use "we" in an attempt to move away from the individual mathematician, which then seems to be a clue to generality.

It is clear that the pronouns "I", "you" and "we" give us an idea of how students position themselves while engaging with a mathematics problem. The referent(s) may be clear, such as when "I" refers to the speaker, and "you" to the audience (single or multiple), or they may overlap:; "I" and "you" can be used to refer to the speaker, while "you" and "we" can be used to detach the speaker from immediate reference and hence make a generalisation. Furthermore, speakers commonly use pronouns in an irregular way, with the effect of conveying a range of social dimensions to themselves and their audience (Rowland, 1999). Rowland observes that the variations in the use of pronouns can be associated with delicate shifts in social positioning of the speaker in relation to his/her audience, such as in owning up to something as an individual ("I") or as a group ("we"), or in partially dissociating oneself ("you"). The use of "I" and “you” suggests that mathematics language is not entirely impersonal; rather; personal views may also be expressed. Other referents such as “me” referring to “I” and “us” and “let’s” that refer to more than one person and thus imply the plural “you” or “we” are also considered. The shifts in social positioning noted by Rowland resonate with the shifts in identities and relationships (Gee, 2005, 2011a)[16] discussed earlier under the seven building tasks, underlining the reason that these pronouns are used alongside the two building tasks in the analysis. It should be noted that when analysing utterances involving the pronouns “you” and “we”, decoding the co-referential becomes complex. Therefore, multiple meanings may be derived.

In this thesis pronouns are used together with aspects of identity and relationship building tasks to analyse the identities and activities enacted by participants. In particular, the focus is on how trilingual students use these pronouns when talking within and about a mathematics task. Do they express their understanding in a personalised and particular way or in a detached and general form, or both, and when do they do so?

The building tasks, together with the pronouns discussed above, are used to analyse student Discourses in order to determine whether, how and why trilingual students use language as they do in moment-to-moment engagement with mathematics. In order to do so, it is important to understand ways of looking at language-in-use that will help us to understand how these building tasks are carried out. One way of looking at language-in-use is through the use of “tools of inquiry”.

4.3.2 Tools of inquiry

Tools of inquiry are “thinking devices” that guide discourse analysts in asking certain questions about the seven building tasks (Gee, 2005, 2011a). The tools that are of interest to this study are social languages, Discourses, situated meanings and Discourse

[16] For example, Gee (2005, 2011a) explains how one speaker (Jane) positioned herself using different social languages in different contexts.

models. According to Gee (2005, 2011a), social languages and Discourses are primarily relevant to how people build identities and activities and recognise those that others are building around them. These tools help us to talk about, and thus construct and construe the world. Situated meanings and Discourse models are tools of inquiry that deal primarily with the intricacies of how language is used (Gee, 2005, 2011a). Gee observes that these latter tools guide inquiry with regard to specific sorts of data and specific sorts of issues and questions. It should be kept in mind, however, that these tools do not work independently but are integrated one with the other. They help us to understand how the building tasks are carried out and the social and political consequences that come with them (Gee, 2005, 2011a). In what follows, I discuss these tools that are relevant to this study.

4.3.2.1 Social languages

Social languages are varieties of language that allow us to express different socially significant identities and enact different socially meaningful activities (Gee, 2005, 2011a). Gee observes that all languages are composed of many different social languages. According to Gee, social languages include, for instance, the language of scientists or mathematicians, and formal and informal languages within any variety of language. For example, one can talk and write as mathematicians do, thus assuming the identity of a mathematician, and enact socially meaningful activities like offering a proof in mathematics. In fact, we all learn and speak social languages and we are able to control different social languages and switch between them in various contexts (Gee 2005).

Gee (2005) argues that a single written or oral text may be in one social language or it may switch between two or more or even mix them up. The social languages may involve one or multiple national languages. A mixture of social languages may portray a speaker as enacting multiple identities within an utterance or as enacting a single identity whose characteristics are a hybrid of multiple social languages.

Each social language has its distinctive grammar (Gee, 2005, 2011a). Gee identifies two sorts of grammar that are important to social languages. There is what he calls "grammar 1", the traditional set of units such as nouns, verbs, inflections, phrases and clauses. "Grammar 2" comprises the "rules" by which grammatical units like nouns and verbs, phrases and clauses are used to create patterns that signal to us and others the characteristic social identities and social activities that we are enacting. The patterns so created may signal, for example, a formal social language as compared to an informal social language.

Gee (2005) argues further that "grammar 2" can be used to pattern text so that compound meanings can be drawn from a single text. He uses the following sentence as an example: "Lung cancer death rates are clearly associated with an increase in smoking", which when interpreted in terms of "grammar 2" has 112 possible and different meanings (Gee, 2005: 42). In deriving the multiple meanings that such a sentence has, it is understood that meaning is not merely a matter of decoding grammar; it is also and more importantly a matter of knowing which of the many inferences that one can draw from an utterance are relevant. Thus any content is available through a social language, and the content gives meaning to that form of language.

Students learn social languages; for example, they learn the mathematics register which involves learning words and ways of speaking, reading and writing in their specific mathematics class at school. The mathematics register, as highlighted in Chapter 2 Section 2.2, uses words from ordinary English, giving them specialised meanings and using them in a specialised way (see Pimm, 1991). As such, the mathematics register and its attendant ways of speaking, reading and writing is a distinctive social language learnt within the context of mathematics. When students use this register during a mathematics lesson or when responding to a mathematics task, they display their understanding of mathematics ideas in connection with the task.

Similarly, both formal and informal mathematics languages (see Pimm, 1991 & Setati &

Adler, 2000) discussed in Chapter 2 Section 2.2.1, are social languages used in mathematics classrooms. Students use informal mathematics language in everyday life to express their mathematics ideas. At school, they learn the formal mathematics language that is valued in school mathematics. While it is important to assist students to move from informal to formal mathematics language (Pimm, 1991; Moschkovich, 2003; Setati & Adler, 2000), it is also important to take into consideration the mathematics involved in both social languages, because students can talk differently about the same thing using the two social languages. For instance, the use of formal mathematics language in the context of geometry can inform hearers of students' in-depth competence in aspects of geometry. On the other hand, the use of informal language in the same area may also show that a student is competent in geometry using everyday language. In this case, students need to be guided in moving to knowing and using formal mathematics language. Furthermore, for trilingual students, the social languages may also involve communicating such understanding in any of the three languages in their repertoire or code switching between them.

The meanings communicated by social languages rely on language-in-use alone. The use of social languages alone is therefore inadequate in understanding meanings that utterances have and in assessing how students communicate mathematically; when people speak or write, their utterances are combined and integrated with non-language "stuff", which Gee (2005, 2011a) refers to as Discourses. Therefore, in attempting to understand students' utterances, it is necessary to understand Discourses.

4.3.2.2 Discourses

Discourse (with an uppercase D) refers to ways of combining and integrating language with non-language "stuff" to enact particular sorts of socially recognisable identities and activities (Gee, 2005). As discussed in Chapter 2, Section 2.2.2, the non-language "stuff" includes characteristic ways of doing things such as thinking and acting, using symbols and objects in the right way and in the right place. Gee (2005, 2011a) says that when we use language together with non-language "stuff" we project ourselves as certain kinds of persons (a "who") engaged in certain kinds of activities (a "what"). He argues that our utterances have meaning only if and when they communicate a "who" and a "what". A "who" is a socially situated identity that one is seeking to enact here-and-now, while a "what" is a socially situated activity that one's utterances help to constitute. If the activity and identity are recognised, then one will have "pulled off" a Discourse of a sort (Gee, 2005: 23). Furthermore, Gee notes that if the activity and identity are different from what has been done before but still recognisable, they can simultaneously change and transform Discourses. If they are not recognisable, then one is not "in" the Discourse.

Gee (2005) observes that identities and activities are not discrete and separable but, rather, interconnected. This is because while one is recognised with an identity partly because of the activity one is engaged in, this activity is also partly recognised for what it is that the identity portrays. The identities we project are multiple and can be flexibly negotiated in the actual context of practice (Gee 2005, 2011a). For instance, one can project different identities in the same or in different contexts, depending on the interlocutor one is engaged with. The different identities, and their concomitant ways of talking, acting, and interacting, may align, overlap, or even conflict with each other in other people's views as well as in an individual's own mind. Hence, the identities and activities may sometimes be clear and at other times opaque. Based on the fact that identities and activities are flexible, negotiable, may conflict, are multiple with contestable boundaries, then the Discourses that can be "pulled off" are also flexible, negotiable, may conflict, are multiple with contestable boundaries. (Gee 2005, 2011a). In the process, some Discourses may die and new ones emerge.

The notion of Discourses has been used by researchers in mathematics education such as Moschkovich (2002) and Setati (2005). Using a situated and socio-cultural perspective[17] and the notion of Discourses (in Gee, 1996), Moschkovich (2002: 198) observed that mathematical Discourses involve “ways of talking, acting, interacting, thinking, believing, reading, and writing, mathematical values, beliefs, and points of view of a situation”. In other words, mathematical Discourses constitute ways of combining and integrating language with other non-language “stuff”, and ways of saying, doing and being in mathematics. In participation in classroom mathematics, Discourse practices thus involve talking and acting in ways that mathematically competent people talk and act (Khisty, 2006; Moschkovich, 2002, 2003). In particular, practices that count as participation in competent mathematical Discourse include particular modes of argument such as precision, brevity, logical coherence, abstracting and generalising, imagining, visualising, making mathematical connections, assumptions and using mathematical representations, justifying, gesturing and predicting (see Moschkovich, 2002). Furthermore, Moschkovich (2002) observes that mathematics Discourses involve different communities such as mathematicians, research mathematicians, and students, and different genres such as explanations, proofs and presentations.

In order to be recognised as competent in mathematics Discourse, trilingual mathematics students need to engage with mathematics tasks in ways that are acceptable in the mathematics Discourse community by developing practices that are acceptable within mathematics Discourse. They learn these practices through interaction with others such as teachers, with books and with tools such as calculators and mathematical tables, non-tangible things like formulae and discussions with peers and “social others”. It is in such interactions that negotiations of meanings occur and different and multiple ways of doing mathematical tasks are likely to be found. With time and continued practice, and by building and rebuilding mathematical arguments, students develop mathematical competence in spoken and written mathematics and ways of acting and being in mathematics Discourse. If they project the ways of being in mathematics that can be

[17] The situated and socio-cultural perspective looks at the situational resources students use and ways that mathematics Discourses are relevant to the situation.

identified with mathematics Discourse, enacting socially situated identities and activities within mathematics Discourse, then they will have acquired the educated discourse, which is the specific way of using language (Mercer, 1995) in mathematics. Thus through learning and teaching trilingual students are exposed to a range of mathematics Discourses. In this regard, this study will reveal a range of mathematical Discourses that the selected trilingual students draw on and enact as they engage with mathematics.

In this study, Discourses helped me to identify and understand the identities and activities that trilingual mathematics students demonstrated when they used language plus other non-language "stuff" to engage with a mathematics task. In order to gain a better understanding of these identities and activities, we need to understand the meanings of words or utterances in the actual context of their use. In other words, we need to understand the "situated meanings".

4.3.2.3 Situated meanings

Whenever they are used, words have multiple and flexible meanings. It is imperative to understand the meanings of words in the specific context of their use (Gee, 2005). According to Gee (2005), situated meanings consider meaning in actual specific interactions between language and context. Although there are other ways of doing discourse analysis, for instance form-function analysis, Gee observes that most often the real action of discourse analysis is at the level of analysing situated meanings (Gee, 2005, 2011a). A focus on situated meanings of words was relevant in this study because one aspect that was explored was how the students used language(s) composed of words; words used in the specific context of engaging in a mathematics task.

Situated meanings analysis involves the analysis of utterances in actual and specific contexts. Context here refers to a set of factors that accompany language; for instance, language that comes before and after an utterance, cultural and institutional factors, people present, and the social relationship between those involved (Gee, 2005). In the context of this study, institutional factors may refer to institutional language policy;

people present may refer to other students and lecturers, while social relationships may involve student-student, student-lecturer, and student-researcher relationships.

The relationship between language and context assumes a reflexive property; an utterance influences what we take to be context and context in turn influences what we take an utterance to mean (Gee, 2005, 2011a). For instance, in a mathematics discussion, the use of a formal mathematics language may signal the presence of a knowledgeable other such as a lecturer, while this presence may prompt the use of formal mathematics language.

The meanings of words and phrases of a language and other non-language “stuff” are created and adapted to a specific context of use, and are relative to and acceptable in a specific Discourse community. However, situated meanings of words, phrases and other non-language “stuff” may differ within a specific Discourse and across Discourses (Gee, 2005).

Studies in mathematics education (e.g. Mestre, 1988; Pimm, 1987) cite examples that illuminate situated meanings. For instance, Mestre (1988) shows that while the word “product” is used in mathematics Discourse, it has different meanings in ordinary English and mathematical English, both of which are part and parcel of the mathematics register. Mestre (1988) observes that in natural discourse, or ordinary English in Pimm’s (1987) terms, a “product” is an item sold in a store, whereas in mathematics discourse, “product” is the result of multiplication. Either of the two meanings of the word “product” can be used in mathematics. Therefore, given a mathematics task, a trilingual student, for instance, needs to tease out the meaning of the word “product” in its actual and specific context of use, to negotiate its meaning using past knowledge and experiences from mathematics and everyday experiences with the word, all with reference to the expectations of the task. If the student’s situated meaning deviates from the task expectation, then s/he will be operating in a different Discourse. Furthermore, situated meanings are associated with patterns of features within context.

The human mind recognises or assembles patterns of features on the spot, adapts, sustains, transforms and builds upon these, resulting in meanings grounded in actual practice and experience in certain ways and not others (Gee, 2005). Given a mathematics task, a trilingual student may recognise or assemble a range of ideas given the words in the task. For instance, the presence of a quadratic formula in a word problem may trigger a pattern of ideas including identification of variables, formation of simple and quadratic equations, and solving for the variables.

However, patterns by themselves cannot explain the situated meanings; rather, they need to make sense of some kind of "cause-effect model" or "explanatory theory" (Gee, 2005, 60). These "theories" explain why the situated meanings have the meanings they have. Gee refers to these "explanatory theories" as Discourse models (these models will be discussed in greater detail in the following section). The process of assembling situated meanings is an active process and is always relative to our socio-culturally defined experiences in the world and more or less "normed" through Discourse models and various socio-cultural practices of the Discourse to which we belong.

Gee observes that situated meanings do not reside in individuals' minds; rather, they are distributed in the practices and settings of cultural groups, books and media. Often they are negotiated in and through communicative social interactions. Similarly, in a mathematics classroom situation, the ways of thinking and using various symbols that teachers and students engage with are guided by the acceptable mathematical practices within the mathematics Discourse. They use the culturally constructed tools such as calculators and formulae as they make sense of tasks, negotiating and renegotiating meanings in the context of use and based on past experience.

The discussion has demonstrated that situated meanings are associated with patterns that the human mind assembles. In order to make sense of situated meanings, we need to select the patterns and sub-patterns that are relevant in a particular context. The guide to this selection resides in the Discourse models of an individual's socio-cultural group and the social practices and settings in which he or she is rooted.

4.3.2.4 Discourse Models

Discourse models are “theories” that we hold, often unconsciously, and that help us to make sense of utterances and the world (Gee, 2005, 2011a). These theories are connected to specific Discourses that we enact. Discourse models are our “first thoughts” or “taken-for-granted” assumptions that function to set up what counts as “normal” or “typical” against what we take to be “non-normal” or “non-typical (Gee, 2005: 72). The models are rooted in our experiences, and it is from these experiences that we learn them. Our experiences are shaped and normed by the social and cultural groups to which we belong and their attendant Discourses. From these experiences, Gee (2005) observes that we infer what is essential, “normal” or “typical” and tend to act on these assumptions unless we are faced with clear exceptions. He argues that, based on what we take to be “normal” or “typical” as opposed to what we regard as “non-normal” or “non-typical” in our social and cultural groups, Discourse models involve making exclusions. These exclusions are not obvious and we are often unaware of making them.

Gee (2005) observes that words or phrases are not necessarily used in terms of their dictionary meanings, but rather against a set of social and Discourse assumptions of a social and cultural group. The meanings depend on what a social and cultural group views as normal in their context. For instance, the Discourse model behind the word “bachelor” may in some contexts involve not just men who are “eminently marriageable” when they stay unmarried, but also unmarried women (Gee, 2005: 71–73). This gives the word “bachelor” a new situated meaning and applies it against the backdrop of a new Discourse model. Meanings are thus not general or abstract but situated in specific social and Discourse practices of social and cultural groups; they are continually transformed by these practices. Thus Gee (2005) argues that Discourse models “explain”, relative to the standards of a social and cultural group, why words have the various situated meanings they do.

Since meanings in Discourse practices are continuously being transformed, then Discourse models are continually revised, modified and developed. This happens either consciously or unconsciously when people interact with others in the socio-cultural group as well as through books and other media (Gee, 2005). Gee explains that when this happens, situated meanings correspondingly change, because the "theory" that was explaining the meaning has been altered. Within mathematics Discourse, these changes help us to acknowledge the development that takes place when certain practices in mathematics are modified or changed and new ways emerge.

Gee links Discourse models to simulations that run in our minds (2005). Simulations are the imaginings that we run in our minds. These simulations are based on our experiences with the world; they take certain perspectives depending on the context that we are in and help us make sense of the situations with which we are faced. However, if we lack (enough) experience in some things, then we cannot run enough simulations to help us make sense of these situations.

Since we share our experiences of the world with other individuals who belong to our socio-cultural groups (Gee, 2005), some of our experiences overlap while others are just sufficiently similar for us to communicate and act together. For instance, trilingual students may share the meaning of the word "hall", but with some differences, similarities and overlaps. The overlaps help them to communicate and act together. What does not overlap is not shared; this could include ideas that are new to either party that supplement the already acquired knowledge about a "hall".

Discourse models are complexly, though flexibly, organised. As such, people portray many and sometimes diverse models, smaller and bigger models, and competing and conflicting Discourse models. Smaller Discourse models are situated inside larger ones. Each is associated with others, in different ways and in different settings for different socio-cultural groups. Sets of associated smaller Discourse models form "master" Discourse models. These master models help to shape and organise important aspects of experience for particular groups of people. In the study reported on in this thesis, it was necessary to understand whether the trilingual students displayed master Discourse models, and how these models related to each other and to smaller models. Through analysis of the smaller Discourse models of individual trilingual students and consequently the master Discourse models, I identified the main themes that emerged.

By using the simulations formed to make sense of the situations we are in, Gee (2005) argues that our expressions (verbal and non-verbal) position us as acting from a given perspective. Understanding this perspective enables us to recognise the Discourse models enacted. In turn, these Discourse models help us to explain the situated meanings for various words. We can thus understand the meanings attributed to words combined and integrated with non-language "stuff" within and across Discourses and thereby identify the kind of identities involved and the type of activities enacted.

In this study, Gee's Discourse analysis is used as an analytical lens; this underlines the importance of describing the seven building tasks that we build whenever we use language.

This section has described the tools of inquiry used to ask questions about the seven building tasks. It is clear from the discussion that the tools do not work in isolation; rather, each reinforces the work of the other. This means that to ask questions about the building tasks we need to know how the tools of inquiry are used because that will allow us to analyse how language is used to enact specific social activities and social identities. The section that follows explains how the tools of inquiry are used to ask questions about the building tasks.

4.4 Method of Discourse analysis

In essence, discourse analysis involves asking questions about how, at a given time and place, language is used to construe the aspects of the situational network as realised at that time and place, and how aspects of the situational network simultaneously give meaning to the language (Gee, 2005, 2011a). Given this reflexive property of language and situation, Gee (2005, 2011a) observes that discourse analysts are interested in analysing situations in which language is used. Such situations involve the contexts in which building tasks take place. He refers to these situations as discourse situations.

All aspects of a discourse situation together constitute an interrelated network within which each of the components of the building tasks simultaneously gives meaning to all the others and gets meaning from them (Gee, 2005, 2011a). Discourse analysis focuses on this interrelated network of language used in the situational network.

Any piece of language, oral or written, used in a situational network is composed of a set of grammatical cues and clues (Gee, 2005, 2011a). The cues and clues are part and parcel of “grammar 1” and “grammar 2”, which are important in social languages (see section 4.3.2.1). They contribute differently to the seven tasks and they guide us in identifying which of the building tasks are being constructed. They are carried out all at once and together. Citing the example of his student Jane, Gee (2011a: 82–84) explains the different cues and clues in Jane’s utterances when she speaks to her parents and to her boyfriend on the same issue. When talking about the same character in a story to her parents, Jane says “Well, when I thought about it, I don’t know, it seemed to me Gregory should be the most offensive …,” while to her boyfriend she says, “What an ass that guy was, you know, her boyfriend”. Gee (2011a) observes that these utterances are in two different social languages and elicit different cues and clues. Furthermore, the cues and clues in the respective utterances were built at the same time and together and the patterns established are part and parcel of “grammar 2”.

Like Jane, trilingual students control many different social languages and switch among them in different contexts. They also mix social languages in complex ways for specific purposes. In fact, they can mix or switch between different social languages that are drawn from different languages, at the level of national languages such as English or Kiswahili or home languages. As a result, several of cues and clues are evident in their social languages.

These cues and clues help to assemble here-and-now situated meanings through which the seven building tasks are accomplished (Gee, 2005, 2011a). In their turn the situated meanings activate certain Discourse models. Finally the social languages, situated meanings, and Discourse models at play allow people to enact and recognise different Discourses at work. Therefore, what is important to Discourse analysis is the social languages, each with its somewhat different and characteristic grammatical resources that are used to carry out the seven building tasks. This study identified similar patterns of grammatical features that were indicative of particular kinds of social languages that the trilingual students uttered as they worked on and reflected on a mathematics task.

Having discussed the tools of inquiry, we are now in a better position to ask certain questions about the seven building tasks. Gee (2005) notes that not all building tasks are equally relevant in all situations; as such, an analyst may not ask all 26 questions Gee (2005: 110 - 113) has proposed but may add other, related questions to some of the building tasks that will illuminate the theme or the question of interest to the study. For the purposes of analysing the trilingual students' social languages in this study, some of Gee's 26 questions on Discourse situations were adapted and other details of language that appeared relevant to this study were added. These, together with indicators of patterns of grammatical features in social languages, are presented in the table below.

Table 4.1 Analysing the cues and clues in the social languages

Question(s)	Discourse situation	Social language question on the Discourse situation	Indicators of patterns of grammatical features in the social language from transcripts
Students' utterances from transcripts	**Significance** – How and what things mean – the sorts of meaning and significance they are given is a component of the situation.	(i) What social languages are involved in the? (ii) What sorts of "grammar 2" patterns indicate this? (iii) How are they made significant?	Words, phrases and actions used to show importance of what is being communicated and how they are used, for example words that indicate formal and informal mathematics languages.
	Activity – Some activity or set of activities is a component of this situation.	(i) What socially situated activities do these social languages enact? (ii) What actions compose these sub-activities and activities?	The activity that the participant is involved in, e.g. offering explanations, justifications, identification, presenting arguments.
	Identity – Any situation involves identities as a component, the identities that the people involved are enacting and recognising as consequential.	(i) What identities, with their concomitant personal, social, … values, appear to be relevant to, taken for granted, or under construction in the situation? (ii) How are the identities stabilised or transformed?	(i) Use of pronouns "we", "you" and "I" (ii) Movement (or not) across the pronouns "we", "I" and "you" (iii) Identifying with (or not) mathematics Discourse community
	Relationship – Any situation involves relationships as a component, the relationships that the people involved enact and contract with each other and recognise as operative.	(i) What sorts of social relationships seem to be relevant or under construction in the situation? (ii) How are they stabilised or transformed in the situation?	(i) Use of pronouns "we", "I" and "you" (ii) Movement (or not) across the pronouns "we", "I" and "you" (iii) Relationship (or not) with mathematics Discourse Community
	Politics- Any situation involves social goods and views on their distribution as a component.	(i) What social goods (e.g. status, power, aspects of gender, race and class or more narrowly defined social networks and identities) are relevant (or irrelevant) in this situation? (ii) How are they made relevant (or irrelevant), and in what ways?	Identification of social goods associated with first-year algebra mathematics module: for example, ability to formulate and solve quadratic functions and equations.

	Connections – In any situation, things are connected or disconnected, relevant or irrelevant to each other, in certain ways.	(i) What sorts of connections are made within and across utterances and large stretches of the interaction? (ii) What sorts of connections are made to previous or future interactions, to other people, ideas, texts, things, institutions, and Discourses outside the current situation?	Connection within and across content of the task Connection to mathematical register, formal and informal languages, conceptual and calculational discourses
	Sign systems and knowledge – In any situation, one or more sign systems and various ways of knowing are operative, oriented to, and valued or devalued in certain ways.	(i) What sign systems are relevant (or irrelevant) in the situation? How are they made relevant (irrelevant), and in what ways? (ii) What system of knowledge and ways of knowing are relevant (irrelevant) in the situation? (iii) How are they made relevant (irrelevant), and in what ways? (iv) What languages in the sense of "national" languages, such as English, Russian or Hausa, are relevant (irrelevant) in this situation? (v)What social languages are relevant (irrelevant) in the situation? How are they made relevant (or irrelevant), and in what ways?	(i) Use of language in tandem with actions (ii) Use of different national languages (iii) Use of mathematical language practices, e.g. conditional statements, making assumptions, providing justification

As noted earlier, the building tasks are integrally linked. This implies that patterns of grammatical features in the social language may be indicated simultaneously through the same or similar words, phrases and actions.

Gee advises that one should pick some key words and phrases, or families of them, from the utterances in the social languages and ask what situated meanings these words and phrases appear to have in the data, in the context in which the data was collected. Thus for the purpose of assembling the situated meanings and identifying Discourse models and Discourse at play, the following questions were relevant in this study (Gee, 2005: 110–111);

1. What are the situated meanings of some of the words and phrases that are important in the situation?
2. What situated meanings and values are attached to places, times, bodies, people, objects, artefacts and institutions relevant in this situation?
3. What Discourse models are at play in connecting and integrating these situated meanings?
4. In terms of identities, activities and relationships, what Discourses are relevant (or irrelevant) in the situation? How are they made relevant (or irrelevant), and in what ways?
5. What institutions and/or Discourses are (re-)produced in this situation and how are they stabilised or transformed in the act?[18]

Having presented the method that I used when analysing my data, it is necessary now to explain how the tools were used in the particular context of trilingual students, as well as the assumptions I made in the analysis.

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[18] In Chapters 6, 7, 8 and 9, I will refer to the table 4.1 above and the five questions on situated meanings, Discourse models and Discourses.

4.4.1 Discourse analysis of some trilingual undergraduate mathematics students' language practices

In order to explore the language practices in mathematics of trilingual undergraduate students, this study used social languages, Discourses, situated meanings and Discourse models to ask questions about the seven building tasks, as discussed above. Social language(s) involved in students' utterances were identified. The analysis therefore describes how and why the students used certain social languages specifically within the context of their algebra task, and in mathematics more generally. This was achieved by examining their verbal and non-verbal utterances.

In using situated meanings as a tool to analyse trilingual students' utterances, attention was focused on meaning(s) in the actual and the specific context of use that could be drawn from some of the words and phrases used by the students, taking into consideration the Discourses in which they were operating. Here it became necessary to understand the perspective that was assumed in using particular words and phrases. The focus on situated meanings was not only in their use of English but also of their other languages. In order to make sense of the situated meanings, I explored the Discourse models of each student's social cultural group, social practices and settings in which they operated. A combination of the social languages, situated meanings and Discourse models informed the Discourses that each trilingual student enacted and the common Discourses that emerged.

4.4.2 Assumptions made in the Discourse analysis

If a theory is to hold, it is necessary that the assumptions are stated. The assumptions of discourse analysis as articulated by Gee (2005, 2011a) are adopted in this thesis. Gee (2005, 2011a) argues that discourse analysis is guided by one foundational assumption: "that everyone has 'good reasons' and makes 'deep sense' in terms of their own socio-culturally specific ways of talking, listening (writing, reading), acting, interacting, valuing, believing, and feeling” (2005: 93). In this connection, this study also assumes that all students had “good reasons” and made “deep sense” of their texts based on their ways of being in mathematics and ways of talking, writing, gesturing, valuing, and interacting as mathematics students and their ways of being in the larger community when they were not engaging with mathematics. In this regard, their texts were taken to be what they meant to communicate at the time. That said, the analysis of data in this study took into consideration the fact that when people speak they are not always conscious of what they mean and do (Gee, 2005).

Initially, I formed the assumption that the participants might not have performed well in English, like my own students and me, as described in Chapter 1, Section 1.1. This assumption was, however, overturned when I realised that the English grades of the students in the study were above the expected threshold level.

4.5 Conclusion

This chapter has outlined the methods of Discourse analysis that informed the analysis of data in this study. The discussion included the seven building tasks that are built and rebuilt when using language and non-language “stuff”, as well as the tools of inquiry as posited by Gee (2005). These are the social languages, Discourses, situated meanings and Discourse models. This chapter also highlighted the fact that tools of inquiry allow people to enact and recognise different Discourses at work – to see them as enacting certain identities when engaged in certain activities. In this study, these are necessary in order to understand the range of identities and activities that trilingual undergraduate students enacted as they used the languages at their disposal to make sense of mathematics tasks. How the actual analysis was undertaken is described in Chapter 6.

Chapter 5 presents a detailed description of the research design and methodology that was used in this study. In the chapter I present the research approach, methods of data collection as well as the ethical considerations.

CHAPTER 5

RESEARCH DESIGN AND METHODOLOGY

5.1 Introduction

This chapter describes in detail the research design and methodology adopted in this study. The sampling procedure and methods of data collection are discussed as well as the rationale behind the methodological choices. Before describing the research design and methodology, the questions that guided this study are recapped. These were:

1. How do some trilingual undergraduate students in Kenya use their languages when solving mathematics tasks?
2. What language practices do these trilingual undergraduate students use when engaging with given mathematics tasks?
3. Why do these students use their languages as they do?

In order to address these questions, an appropriate research design and methodology was required. These are discussed below.

5.2 Research Design

In order to gather data to explore whether, how and why trilingual undergraduate students in Kenya use their languages to make sense of mathematics, I adopted a qualitative research process[19]. Qualitative research is an inquiry process that explores and seeks to understand a social or human problem (see e.g. Creswell, 2012). According to Creswell (1994), in exploratory research, the researcher does not have predetermined knowledge of what will happen in the research. A qualitative inquiry process "enables researchers to learn firsthand, about the social world they are investigating by means of

[19] Researchers refer to qualitative research as an approach or inquiry process (see e.g. Hitchcock & Hughes, 1995 and Creswell, 2009, 2012). Since they refer to similar features of qualitative research, I choose to use the term inquiry process and reserve the term approach to refer to the different methodologies in which qualitative research can be conducted, as used by Creswell (2012).

involvement and participating in that world through a focus upon which individual actors say and do" (Hitchcock & Hughes, 1995: 12). Hitchcock and Hughes argue that this approach places individual actors central to the investigation and focuses on context and meaning. Qualitative researchers (see e.g. Creswell, 2012; Hitchcock & Hughes, 1995) explain some features of this inquiry process as being that data is collected in the natural settings of the respondents and that the researcher is the key data collection instrument. Multiple methods of collecting data may be employed; the researcher keeps the focus on learning the understanding that the participants have of a problem or issue and not the meaning that the researcher brings to the research. The phases of the research process may change or shift once the researcher enters the field and begins to collect data; this means that the researcher's position and participation in the research should be stated at the outset.

Given the main features of an inquiry process mentioned above, I found a qualitative inquiry process to be appropriate for this study, which sought to understand language practices of trilingual undergraduate students while engaging with mathematics. In this study, I was the primary data-collection instrument and was thus involved throughout the research process. As a researcher in the given context, I understood English as well as the two local languages, Kikuyu and Kiswahili that were common among the students participating in this study and in the wider research site of a university in Kenya, details of which are discussed later in the chapter. Furthermore, I was confident in engaging with the university at large and the participants in particular since I had experience in lecturing mathematics in higher education in the country. However, I did not have the knowledge of how the participants used language, and although the students had made choices on the languages for participation in the study (as will be explained later in this chapter), I had no control over how they would use the language(s). I obtained data first-hand from the participants through different data collection instruments.

My choice of a qualitative inquiry process was also based on the fact that it is informed and guided by the constructivist paradigm, which is the theoretical framework that informed this study. The constructivism paradigm holds that meaning is socially constructed by individuals involved in the research situation (Creswell, 1994, 2009, 2012; Guba & Lincoln, 1994). The meanings are varied and multiple and are negotiated socially and historically as individuals interact with "social others" (Vygotsky, 1986). This is consistent with the view that words whenever used have multiple and flexible meanings, therefore their meanings should be understood in the specific context of use (Gee, 2005), as discussed in chapter 4, Section 4.3.2.3. The meanings that individual students have developed about their language practices over time as they interact with their peers, teachers and others outside the school environment, and those that they constructed as they engaged with the researcher were of outmost importance. In making the choice of a qualitative inquiry process, I anticipated these constructivist attributes. The qualitative inquiry process takes a range of methodological approaches to inquiry. I chose a case study approach.

5.2.1 Why the choice of a case study?

A qualitative case study is an approach in which the researcher explores a real life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, using multiple lenses, through detailed, in-depth data collection process involving multiple sources of information, reporting a case description and case themes (Creswell, 2012). Creswell (2012) notes that, the hallmark of a good qualitative case study is that, it presents an in-depth understanding of the case. Case study approach is appropriate when in among others; the focus of the study is to answer "how" and "why" questions, and the researcher cannot manipulate the behaviour of study participants (Yin, 2003). Creswell (2012) observes that case studies may be distinguished by the intent of the case analysis.

Three variations exist in terms of intent: a single instrumental case study, collective or multiple case studies, and an intrinsic case study.

Since my focus in this study was to explore the language practices of students, the multiple case studies approach was most appropriate. In multiple case studies, the issue or concern is selected and the researcher selects multiple case studies to illustrate the issue (Creswell, 2012). The researcher selects several programmes from several research sites or multiple programmes within a single site. Multiple cases are important in revealing different perspectives on an issue and the researcher replicates the procedures for each case. Yin, (2003), notes that a case study should be bounded so that the researcher works within a reasonable scope. For instance, a case can be bound by time and place, time and activity or by context. Further each case forms a unit of analysis in the study.

I explored the language practices of students at one site; specifically, one university in Kenya. I purposefully selected multiple cases of individual trilingual undergraduate students, cases within a case. I used similar procedures in each case to show the different ways that language(s) were used. This purposeful selection of individuals helped me to collect the relevant data and to seek in-depth understanding of the students' language practices through analysis of the processes, meanings and understanding they gained through words and what was observed. This was done over a period of three months, details of which will be discussed later in this chapter, section 5.3.2.

The rationale underlying the use of a case study is the desire to reproduce social action in its natural setting or real life situation (see e.g. Yin, 1989). Interpretation of social actions in their natural settings are thus of utmost importance in a case. The social action(s) central to my study were the language practices of the students' as they engaged with the given mathematics task. In order to ensure a natural setting for the students, the research was carried out on the university premises. The university environment enabled the participants to provide realistic responses. The mathematical context and the meanings embedded in the communication that occurred through the use of different data collection instruments were all necessary in understanding students' language practices in their mathematical engagements.

In the following section, I explain the methodology used to collect data.

5.3 Methodology

Research methodology provides a road map for the collection of data procedures, the instruments used, and the limitations of a study, its ethical considerations and rigour (see e.g. Hitchcock & Hughes, 1995; Hofstee, 2006). It is advisable that the design of the instruments, their purpose and how well they apply to the study are addressed. The procedure used in collecting the data should be detailed so as to allow for ease in following the procedure as well as to demonstrate the rigour of the research process (Mishler, 1990; Yin, 2003). The ethical considerations describe the process of securing ethical clearance to gain access to the research site, while the limitations are those conditions that may place restrictions on the conclusions and generalisations of the study findings. These are discussed in detail in the Sections 5.3.1 – 5.3.5 that follow.

5.3.1 Instruments for data collection

In this study data were collected using student questionnaires and clinical and reflective interviews with students. The three instruments were administered to each participant. The triangulation of the instruments was intended to ensure the accuracy and consistency of the data collected (see e.g. Hitchcock & Hughes, 1995). In what follows, I discuss the three instruments in the order in which they were applied.

5.3.1.1 The Questionnaire

A structured questionnaire was used to gather the baseline data, which were used for the selection of interview participants. A structured questionnaire has a definite, concrete and predetermined set of questions, and the responses are specific; comments in the respondents' own words are kept to the minimum (Kothari, 2009). In developing the questionnaire, I considered the questions and their wording very carefully so as to ensure that all questions were clear and not ambiguous. The questions were precise and independent of each other.

The questionnaire comprised three sections: general information, education background and language background (see Appendix D). The general information included questions on gender, age, faculty of study and programme for which each student was registered. Education background provided data on the students' scores in English and Mathematics in the Kenya Certificate of Secondary Education (KCSE), while language background provided information on the students' home language, other commonly used languages, and their language of preference for interviews. The questionnaires were numbered so that non-returns could be noted.

A questionnaire has the limitation that the researcher cannot probe the respondent further. Where the research involves exploration of language practices, as in this study, a questionnaire is inadequate since certain aspects of language practice need to be experienced by the researcher in the actual context of their occurrence. For this reason, the study used clinical and reflective interviews as well.

5.3.1.2 The Interviews

In order to capture data that would allow me to explore the language practices of the students, I decided to engage the participants through interviews. An interview is a face-to-face, verbal interchange in which the interviewer, attempts to elicit in-depth information on certain issues from interviewee with the aim of understanding the interviewee's perspectives expressed in his or her own words (McCoy & McCoy, 1954, in Minichiello, Aroni, Timewell, & Alexander, 1990). According to Minichiello et al. (1990), interviews focus, and rely, on verbal accounts of social realities. While the verbal accounts were important in this study, the accompanying non-verbal aspects such as gestures and actions were also captured since they either supported or added to the verbal utterances (see Gee, 2005). I used both clinical and reflective interviews, each of which had different functions in the study.

Clinical interview

The clinical interviews were used to elicit information on language use as the students engaged with the task, explaining each step of their process. A clinical interview is a face-to-face and one-on-one method of interviewing in which the reasoning of the interviewee is explored by intensive questioning, taking into account the accompanying non-verbal forms of communication (Keats, 1997). Clinical interviews were necessary in this study, which closely explored individual students' language practices when solving mathematics tasks.

The interviews used a sequential item chain structure form (Keats, 1997; Minichiello et al., 1990) with some modifications. This structure was such that while the student engaged with the task, the response to the first question of the task informed the second question of the task, and the response to the second question led to the next task question, and so on, thus forming a chain. Other than following the sequential item chain structure, I as the interviewer at times referred to an earlier response or probed further into aspects of interest. As a result of the expected differences in the individual participants' solution processes, unstructured questions were used. The questions and mode of questioning allowed the interviews to flow (see e.g. Opie, 2004) and facilitated ease of understanding of the solution processes involved in the tasks.

Bearing in mind that I used Discourse analysis methods (discussed in Chapter 4, section 4.4) to analyse the data, the purpose of the clinical interviews was to establish how the students combined and integrated language with ways of thinking and valuing, artefacts, and intentions, past behaviours, knowledge, actions and gestures and language practices as they engaged with the mathematics task. How they drew on multiple resources and practices of language that were important in communicating their mathematical understanding, verbally and/or non-verbally was necessary to me to signify the Discourses they were operating within. An example of how the interviews proceeded is as follows: after giving the participant the opportunity to read the task on his/her own, I would then ask, for example, "What is the question requiring you to do? How do you proceed in solving it?"

The interviews were video recorded and field notes were taken after the interviews. The interviews were expected to address to the following research questions;

1. How do some trilingual undergraduate students in Kenya use their languages when solving mathematics tasks?
2. What language practices do these trilingual undergraduate students use when engaging with given mathematics tasks?

The clinical interviews allowed for flexibility as I pursued the information of interest in the direction that the participants took (see Creswell, 1994; Hitchcock & Hughes, 1995; Patton, 2002). Patton, (2002), notes that when a researcher asks interview questions, they may be biased or leading questions. Aware of this issue, I was careful not only of how I asked the questions but also how I phrased them.

In order to complete the triangulation of the data collection method, the study also used reflective interviews.

Reflective interview

The aim of using reflective interviews in this study was to identify, ascertain and confirm various actions, different languages and language practices that were used but that may not have been visible during the clinical interview. Research has shown that one of the most viable means of collecting data on language use is through verbal report (see e.g. Cohen 1995; Kern, 1994). Such verbal self-reports provide data on moment-to-moment thoughts and language practices that are a reflection of what the participants do, characterised by generalised statements about their language practices. Thus in this study, the reflective interviews pertained to the participants' reflections on how they had used language and the non-language "stuff" during the clinical interviews. Semi-structured questions were used in this session, with the wording and sequence of the questions being determined by the response to the clinical interview by each participant (see e.g. Merriam 1998; Opie, 2004). Several questions outside the interview schedule were prompted by students' unique responses. Examples of some of these questions are: When you first read the question, what impression did you get? The question was written in English, which other languages did you use as you engaged with the task? These questions, among others, were geared towards clarifying responses in order to address the research questions:

1. How do some trilingual undergraduate students in Kenya use their languages when solving mathematics tasks?
2. What language practices do these trilingual undergraduate students use when engaging with given mathematics tasks?
3. Why do these students use their languages as they do?

Thus these interviews were expected to provide data on whether, how and why the participants used certain language(s) while processing the task, in speech or in writing or by any other non-verbal means. The challenges experienced while engaging with the task and how students coped with these were addressed during these interviews. In order to enhance students' responses, parts of the video that were considered crucial were played for each student. The reflective interviews were video recorded and field notes taken after the interviews.

Before using these research instruments, I carried out a pilot study to test the methods, instruments and procedures that were to be used in the main study.

Pilot study

A pilot study often provides a researcher with ideas, approaches, and clues he/she may not have foreseen before conducting the main study (see e.g. Mugenda & Mugenda, 2003). Such ideas and clues may assist in refining and modifying research questions, the methodology and analytical procedures. In particular, research instruments should be tested prior to the main study (Mugenda and Mugenda, 2003). According to Mugenda and Mugenda (2003), after pilot testing, one may then be able to make the needed alterations to the questions, data collection instruments and procedures, and analytic procedures in preparation for the main study. This can help to reduce unanticipated problems and may lead to a greater chance of achieving valid findings in the main study.

My interest in the pilot study was to test how well my research instruments and data collection procedure would work in the main study. I tested the instruments on four participants from two different public universities, which were different from the university at which I conducted the main study. The two universities and the students had similar characteristics to this university and the students who participated in the main study. However, these universities did not have the diverse programmes in which mathematics was offered like at the university where the main research was conducted (these details are explained in section 5.3.2.1). In testing I checked for instance for clarity of questions and instructions in the questionnaire. I also checked whether the questions asked during the interviews addressed the research questions. From the results of the pilot study, I found that the instruments functioned as expected and therefore they did not need to be adjusted.

The procedures for conducting the interviews were found to require some adjustments in order to facilitate effective data collection. While I had initially assumed that reflective interviews would be easily generated from the clinical interview, I found the need to make individualised questions for each participant. Furthermore, during the pilot study, I observed that some students who completed the questionnaire and participated in the clinical interview did not turn up for the reflective interview. With this in mind, during the main study I included a number of students in case some of them were unavailable or dropped out, in which case the data of those who remained would be reliable in terms of quantity for analysis for my study. I further considered asking them for their mobile phone numbers to facilitate further communication. This experience helped me to make the necessary adjustments and improved my chances of achieving valid findings in the main study.

5.3.2 Data collection procedure

The data collection procedure started with the sampling of the university, programmes and the students enrolled in these programmes. This was followed by the administration of the research questionnaire. The data were analysed in order to select participants for the interviews. Data collected in the interviews formed the primary database for this study. The data collection exercise was conducted on the main campus of the university in the period May 2011 to August 2011.

5.3.2.1 Sampling

I sampled the university, the programmes and the study participants. It was essential that the degree programmes that the students were following included mathematics as a course; first, because the study was concerned with how mathematics students engage with mathematics, and secondly, to ensure that the students felt that the research concerned issues that related to their studies.

The university and the programmes

Using a judgmental sampling procedure, the study focused on one university which offered a range of technological programmes. Bernard (2000: 176 cited in Patton, 2002) observes that “in judgmental sampling, you decide on the purpose you want the informants to serve, and you go out to find some”. With this in mind, I focused on one public university, namely Procity[20] University, which offers programmes with mathematics as a prerequisite subject as well as offering mathematics as a course (module) within these programmes.

Public universities in Kenya receive government’s financial support and students’ tuition is sponsored partly by the state. These universities admit students based on merit and the admission criteria for respective degree programmes, set by JAB (2010). The main admission criterion at these public universities is the cut-off point set using the KCSE results, as discussed in Chapter 1, section 1.5.1.4. Public universities are also regarded as having a variety of programmes. Thus my choice of Procity University was based on the possibility of having students who were admitted to pursue mathematics, science and technological programmes on the grounds of having succeeded in mathematics.

Procity University is located in the central part of Kenya. At the time of data collection, it offered academic programmes in four schools. The School of Engineering was the largest in terms of the number of programmes on offer and number of students (personal communication with the Dean of School of Engineering, Mr A Kimaru, May 2011). Admission to engineering programmes was pegged at some of the highest cut-off points,

[20] A pseudonym used for the university that participated in the main study.

with programmes such as law, technology, and medicine (at other universities). With admission dependent on merit, students from diverse language backgrounds, social class and economic status, and from both rural and urban areas were all to be found at Procity University.

I identified programmes that required students to have succeeded in mathematics as a specific subject in their cluster for university admission purposes, according to JAB's document on programmes on offer at all public universities (Appendix F). From these, I selected the programmes offered by Procity University. These were found in clusters 2, 7, 9 and 11. I further narrowed these down to programmes that did not require English as a specific or an optional subject in the cluster. This choice of programmes was based on the assumption that students admitted to them had lower scores in English than in mathematics[21]. This resulted in my using programmes from clusters 9 and 11. The relevant programmes in these clusters at Procity University were bachelor's degrees in a range of engineering fields and in computer science respectively. The computer science students were not available at the time of data collection. While I needed data from students from a range of programmes, I could not wait for the computer science students to return from their 2 weeks field exercise because my study was time bound (see e.g. Creswell, 2009; Hitchcock & Hughes, 1995; Merriam, 1998; Yin, 1989, 2004) in terms of data collection period and academic level of the students. This meant that I used students from the engineering programmes.

There were seven engineering programmes offered, from which I chose three: bachelor of science degrees in Geomatic Engineering and Geospatial Information Systems, Civil Engineering, and Mechatronics Engineering (hereafter referred to as X, Y and Z respectively). In these programmes, the required cluster subjects were mathematics, physics, chemistry and biology or any group III, IV or V subjects (see Appendix F).

[21] As initially indicated, this was done with the aim of capturing students who had a wide disparity in their marks in the two subjects.

Mathematics is in Group I together with Kiswahili and English while biology, chemistry and physics are in Group II. The programmes had mathematical courses taught across the semesters alongside some general and programme specific courses. During the particular semester of data collection three compulsory mathematical courses were being taught to first-year students. These were Algebra, Geometry and Calculus 1. The choice of a variety of programmes with similar admission criteria was expected to provide similar results, while the difference in the programmes would possibly provide contrasting results.

I had the opportunity to meet and interact with 122 first-year engineering students from the three programmes. It was necessary to consider first-year undergraduates because the background of the study was based on students' mathematics scores in KCSE, which at the time was their most recent main examination result. In addition, it was necessary to determine the language practices that secondary school graduates brought with them to undergraduate studies.

In the first meeting sessions with the students, I was introduced by the mathematics lecturers concerned as a mathematics education researcher. Lecture time tables were available for all programmes; these indicated the lecture times, venue and lecturer for every course. Most theoretical lectures were blocked for two or three hours with practical sessions running for an average of three hours. In courses that were common across the three programmes (and others), lectures were conducted jointly by one lecturer; for example, during this first encounter with the students, those in programme X and Y were attending a joint lecture session in algebra. After the first meeting sessions, I interacted with the students in an effort to build a friendly relationship with them and to ensure my familiarity with their everyday academic activities. During the second session, I administered the questionnaires.

Administration of the Questionnaire

It was my intention to administer the questionnaires two weeks before the first clinical interviews. However, in practice, the instrument was administered one week before the interviews. This was occasioned by the initial absence of one of the lecturers whose students were participating in the study. Later, when the lecturer became available, the questionnaires were administered.

In one class, involving a combination of students enrolled in programmes X and Y, the questionnaires were administered to all 97 students present during the last 20 minutes of the two-hour lecture. During the session, programme X had 60 students and programme Y, 37 students. The questionnaire was also administered to the 25 students in programme Z who were present during the first 10 minutes of their three-hour lecture.

Before responding to the questionnaire, I guided the students through the sections. As they filled in the details, a few students asked questions pertaining to the meaning of the phrase “first language”. While this had been explained earlier, the explanation was reiterated as the need arose. All 122 students to whom the questionnaire was administered completed and returned them (100% return rate). While this return rate is not usual, it was made possible by the fact that the researcher had established a cordial relationship with the students and none was compelled to return the questionnaire. Furthermore, in the second class, the number of students was relatively small; hence it was possible to monitor and request them to return the completed questionnaires. In order to conduct the study, I had to know whether the students would consent to participate in the study or not. They were therefore presented with an informed consent form together with the questionnaire.

The students read the letter explaining the study and filled in the corresponding consent form (see Appendix B). The letter provided information on the study, the students’ role in the study, and how data would be used, confidentiality of the data and how students would access the analysed data. The students consented or not to video coverage during the interviews and the use of the data so collected for educational purposes.

Selection of students and their characteristics

Analysis of the questionnaire data revealed that the students were in the age bracket of 18–22years. There were 11 females and 111 males. Their scores in both mathematics and English ranged from Grade A to Grade B- (B minus); that is, they had succeeded in both subjects. However, they generally scored higher in mathematics than in English. This was not surprising given that the admission criteria for engineering programmes included a combination of mathematics, physics, chemistry and any other subject except English and Kiswahili as earlier indicated in this section.

On matters of language, the 122 students between them spoke 15 indigenous languages as home languages. These were also used as first languages, and they commonly used them at home while Kiswahili and/or English were used as additional languages. Kiswahili and English were frequently used in the academic context in interactions with self, peers and lecturers. Furthermore, the majority of them indicated that they thought in their home language and used it during mathematics discussions with peers with whom they shared a home language. Using the questionnaire data, I selected the interview participants using the criteria discussed below.

The first criterion was consent and completion of the questionnaires. The consent was considered for both video coverage of interview proceedings and possible use of video text for educational purposes. Seventy-eight students (63.93%) consented and completed the questionnaires. The remaining 44 (36.07%) had neither or both; for example, no name on the consent form or no entries on education background.

The second criterion was students' scores in mathematics and English. I used the 75th to 100th percentile range for mathematics and below 25th percentile for English. Using the

Grades A, A-, B+, B, and B- that students had recorded as their scores, I selected students who scored 75% to 100% in mathematics, equivalent to Grade A, 25% and below in English, which corresponded to Grade B- (B minus) for both groups Y and Z and Grade B+ (B plus) and B for group X, which were the least scored Grades in the subject. The differences in the 25th percentile English scores were occasioned by the fact that while a disparity was evident in group X, similar to that in groups Y and Z, the students with similar grades in group X had not consented to being part of the study. It was my assumption that participants' had not done as well in English as they had in mathematics, as was the case with my students when I taught in high school, and also my own personal experience. However, this assumption was disproved by these students' performance in English.

Given that these students met the two criteria, I selected students with a range of home language background, particularly those who indicated that they used languages other than the LoLT while responding to mathematics tasks. A sample of 15 students in total was selected. This sample represented six home languages with the students distributed across them as follows; Dholuo 3, Ekegusii 1, Kikamba 1, Kikuyu 6, Kiswahili 2[22] and Luluhya 2 (see Appendix H).

All the students preferred to be interviewed in English. They had all learnt English in primary school as a second or third language. They were proficient in spoken home language, Kiswahili and English. They were competent in written English as manifest in their scores. However, their performance in written Kiswahili was not available because initially I did not consider that the students could engage in mathematics in Kiswahili, thus I had not requested their scores. As discussed in Chapter 1, section 1.5.1.2, according to the LiEP, indigenous languages, which in this study are students' home languages, are neither studied nor used beyond Standard Three. This means that students

[22] The two students used Kiswahili as their home language but were both Kikuyu first language speakers

in both high school and university do not study their home language, unless it is Kiswahili.

After indicating their willingness and enthusiasm to participate in the study, the 15 were involved in the second part of data collection, the interviews.

Prior to discussing how data were collected in the interviews, it is important to describe the task that the students engaged with during the clinical interviews.

5.3.2.2 The task

The task was an algebraic word problem. Algebra is a branch of mathematics, which deals with structure, relations and quantity. Sykes (1982 cited in Pimm, 1987) describes it as "a branch of mathematics dealing with properties of numbers and quantities by means of letters and other general symbols". It can be expressed in natural language (e.g. English, French) and in symbolic systems (symbolic writings and compound representations, e.g. drawings) (Drouhard & Teppo, 2004).

Algebraic activities occur in our everyday lives (Hewitt, 2001, in Drouhard & Teppo, 2004). According to Hewitt (2001, in Drouhard & Teppo, 2004), the activities may include informal problem solving such as relating quantities. While such activities are utilised and formalised in a mathematics classroom, algebra is gradually taught at different levels throughout the four year course at secondary level in Kenya (Ministry of Education, (MoE), 2002). It is also taught in the first year of undergraduate studies to students in mathematics, science and technological programmes (Jomo Kenyatta University of Agriculture and Technology, (JKUAT)[23] 2008). Algebra is a gatekeeper course for mathematics and the majority of scientific and technical programmes at university level.

A word problem is appropriate to investigate language issues of students who use a

[23] At the time of data collection, Procity University was using the mathematics syllabus of JKUAT since it was a constituent campus of JKUAT

second language as LoLT and as a language of assessment (Newman, 1977). In mathematics, algebraic word problems can be effectively used to investigate language issues among mathematics students (Gerofsky, 1996). In this regard and with my study focusing on language practices during students' engagement with a mathematics task; I deemed it appropriate to use an algebraic word problem. In a word problem, its meaning and procedures of operation need to be extracted first from the sentences in order to proceed to solve it. Sentences are meant to provide real life situations (Orton, 1992). Thus the choice of an algebraic word task in a real life context was made on the assumption that students would be able to relate to such a problem in their own environments and make it explicit and recognisable in their verbal explanation of the solution process as well as in the embedded non-language "stuff". Furthermore, the mathematics tasks in KCSE, which qualified the students for undergraduate studies, were method oriented; in order to score marks, students must show in writing the processes they use to arrive at solutions. This meant that the students in my study were not new to providing the solution process of such tasks.

The specific task was chosen from a standardised KCSE paper offered by KNEC. I followed this course because I assumed that the instructions would be clear, the task unambiguous, the language was at the level of the students, and that the content had been covered in secondary school. Prior to presenting the task to the students, the lecturers confirmed that the task was appropriate for the targeted students, that is, the difficulty level was moderate and the context of the task was familiar to the students. This was further reinforced by the fact that the targeted students were taking algebra as a course during that particular semester.

As is the case in most word problems, the task comprised the information and the questions (see Gerofsky 1996). The information part provided details of the setting and the known values. The setting of the question was an imagined real life situation. The question part provided details of the expectations of the task.

The task was as follows:

Q. A hall can accommodate 600 chairs arranged in rows. Each row has the same number of chairs. The chairs are rearranged such that the number of rows is increased by 5 but the number of chairs per row is decreased by 6.

(a) Find the original number of rows of chairs in the hall.

(b) After the rearrangement, 450 people were seated in the hall leaving the same number of empty chairs in each row. Calculate the number of empty chairs per row.

The task was presented to the students in English; however, parallel versions of the task were also prepared in their home languages, in case any participants required this. In order to facilitate the task, I provided the sampled students with the question paper, writing materials (plain paper, pen, pencil and ruler) and calculator. The expected solution process and the solutions are provided in Appendix J.

5.3.2.3 Conducting the interviews

In order to conduct interviews and collect the anticipated data, a researcher needs to have skills that facilitate the elicitation of the required information from the participant, such as good communication and interpersonal skills (Mugenda and Mugenda, 2003). The researcher should establish a friendly relationship with the interviewees prior to the interviews and provide a physical environment conducive to the elicitation of information. In keeping with these requirements, I prepared for the interviews and practised interviewing skills during the pilot study. I also familiarised myself with the students during the introduction phase and when administering the questionnaires. Furthermore, I interacted with them during one of their Continuous Assessment Tests (CAT) sessions, during which I was requested to assist in administering one of the mathematics CAT in the university auditorium. This was while I waited for one of the interview sessions to begin. The environment in which the interviews were conducted was appropriate in that it was on the university premises and all the facilities that were required were available and students were familiar with them.

As it is with tests, the CATs kept the students very busy as they were revising and attending lectures and practical sessions. This disrupted the scheduled programme for the interviews somewhat, but adjustments were made to accommodate the students. Beyond that, there were exceptional circumstances that prevented students from being available at the rescheduled times. By consulting with them by telephone, we rescheduled again to suit their tight programmes.

Each interview session began with a brief conversation with the participants about their academic life. During this session, the participants were familiarised with the process of the interview and what was expected of them and they were assured that they would not be scored in any way. They were reminded that the interviews would be video recorded. These conversations were meant to reduce students' anxiety before the interviews (see Clarkson, 2006). In order to ensure effective communication during the interviews, I used English language at the level that the participant could understand (see Mugenda & Mugenda, 2003), but the participants were free to explain in any language they chose.

The interviews took place in an office that was shared by two mathematics lecturers, one of whom taught algebra to the first-year students in this study. During the interview period and when not attending a lecture, the two agreed that they would sit in the library or other colleagues' offices. The interview room was near one of the lecture halls where some of the students had algebra lectures. With the schedule of interviews in place, the everyday activities of the office were limited, but once in a while mathematics students would come in to hand in their assignments. At other times, other lecturers would come in looking for their colleagues. In some cases the interview and video coverage would be stopped to attend to the visitors. This generally took a minute or two and then the interview session would resume. The office was not sound proof, thus noise from outside would at times interfere with the communication and the recording of the interviews. Thus some interruptions were experienced, but they were managed as they arose.

Although the environment suggested a natural setting where in principle a qualitative study should be conducted so that events are recorded as they unfold without manipulation (see e.g. Creswell, 2009), the office environment and the engagement with the task in the presence of others[24] may not have provided a natural environment. The interruptions and the environmental factors affected continuity of the interviews; however, this had a negligible effect on the validity of the data. I conducted a total of 30 clinical and reflective interviews with the students, each of which lasted on average 20 minutes.

Conducting the clinical Interviews

In this study, clinical interviews were useful in eliciting information on explicit language practices as the students engaged with the task explained in section 5.3.1.2 above. At the beginning of each clinical interview, each participant was informed of what was expected before embarking on the task. Each of them was given a chance to read the task and go through the questions. When they had done so and indicated that they were ready to start working on it, they were asked to read the task aloud and to describe what it was about and why they thought so. This was intended to enable access to the students' understanding of the task details; its requirements and the process of operating within the mathematics task with the researcher (see Pimm, 1987). They were then requested to argue within the task, explaining each step of the process, and providing justifications for their actions.

[24] Others here involved the researcher and the person who was recording the video.

The students had the option of either doing the task and explaining the solution process as they proceeded, or working on the task first on their own and then explaining this to the researcher. Where the latter option was chosen, no interventions were made until the student signalled that he had finished. This option provided an opportunity for the students to consolidate their ideas and gain confidence when explaining their understanding. Both options were provided with the aim of making the environment more conducive to their participation.

The students' explanations of the solution processes were encouraged by the researcher asking questions and probing further (see e.g. Minichiello et al., 1990; Mugenda and Mugenda, 2003). The solutions were spoken and written, and included sketches and non-verbal language, for instance hand gestures and pointing while explaining (see e.g. Forman, McCormick & Donato, 1998; Gee, 1999, 2005). Since the interview was unstructured, I was flexible in the way I asked questions, depending on the direction that the student took in responding to the task; for instance, asking how certain solutions were arrived at, and confirming some procedure or variables that were used. However, these questions were kept to a minimum in order to give maximum attention to the student's solution process. Furthermore, to focus attention on students' explanations and to maintain rapport, field notes for these interviews were not taken during the interviews but made shortly after the interview session.

Some of the language practices that the students engaged in during the interviews were explicit. For instance, the majority of the students explained the processes of solving the task in English, while others switched between English and Kiswahili in their verbal utterances; however, the written work was in English. Those practices that were not explicit or recognisable were addressed during the reflective interviews. It is important to mention that although this study was not overly concerned with the correctness of the final solution, most of the students finished the task with the desired accuracy. The interview data were later transcribed[25]. I was then able to structure reflective interview questions for each student.

Two explicit challenges posed by the clinical interviews were that they required a great deal of time to collect data in each individual case, about 20 minutes, and the data collected were not in the same order since the questions were unstructured. Time management was addressed by focusing on only the questions of interest. In addition, despite the unstructured format of questions, the researcher made an effort to focus on issues that were of interest to the study. The data collected were used effectively to establish patterns that revealed themes for the study (Gee, 2005). Being the primary data collector and guided by the assumptions of the theory (stated in Chapter 4, section 4.4.2), I made every effort to ensure objectivity in the study, handling the clinical interviews and procedure with the necessary integrity.

Conducting the reflective Interviews

These interviews were conducted after the clinical interviews and at the earliest convenient time for the participant and researcher. Reflective interviews were important in identifying, ascertaining and confirming the range of actions and gestures, different languages and language practices that were used and that were not visible during the clinical interviews (section 5.3.1.2 above). After informing the students of what was expected during these interviews, snapshots of the video were run for each participant to familiarise them with their voices and actions. While Tilley and Powick (2002) observe that watching one's own actions and listening to one's own voice with other people (in this instance video recorder and I) may create some anxiety on the part of the participants, the snapshots were meant to reduce or remove any anxiety during the interview sessions. The replay of the videos was also used to facilitate discussion on how the students had gone about solving the task, and whether they had switched

[25] Transcription of data from both interviews is discussed in detail in Chapter 6, section 6.2.2.

languages and if they had indeed done so, at which stages this had happened. The participants were assured that the interviewer was not interested in any incoherence in the participants' utterances or whether they had finally reached the correct solution of the task. If anything, all the data was to be treated with confidentiality. All this was aimed at making them feel at ease and to encourage them to participate actively in the interviews. The task paper and their work sheets were made available to students for reference if the need arose.

Semi-structured questions on whether, how and why language was used were put to each participant. For more elaborate information and clarity, probing questions were asked (see e.g. Minichiello et al., 1990; Mugenda & Mugenda, 2003). As observed by Minichiello et al. (1990), probing is necessary when the participants' statements seem incomplete, vague or when they give no answer. But even with probing, I cannot claim that the students communicated or expressed all their thoughts and activities related to the interview, since Vygotsky (1978) warns that even if humans communicate their thoughts through verbal and non-verbal means, some thoughts remain unexpressed.

The duration of each interview depended on the number of questions and the way each student responded. On average, each interview lasted 20 minutes. During and immediately after the interviews I took field notes. The interviews yielded rich data on the impression created by the task, the languages used and the actions observed. This was then transcribed.

In conclusion, the instruments and data collection procedures used in the multiple cases within the single research site of Procity University yielded voluminous data in relation to the research questions. The data were also in-depth, detailed and provided insightful explanations of the students' language practices on a very personal level. These data were in the form of recorded spoken words, written words, gestures and actions. The analysis of these data is discussed in the Chapter 6, section 6.3.

As with any study, the methodology used in the current study was not absolute, it had some limitations.

5.3.3 Methodological Limitations

Methodological limitations are aspects that are beyond the control of the researcher and which may place restrictions on the findings of the study and their application to other situations (Best & Kahn, 1998).

It has been observed that qualitative researchers are reluctant to generalise from one case to another because the contexts differ (see Creswell 2012). This was applicable in this study because it concerned a case study of one public university with multiple cases. The sample was rather small (n=15), given that the population of all students who were taking mathematics courses and had higher scores in mathematics than in English was far more than 15. Furthermore, there are other universities in Kenya with students with similar performance characteristics. Hence the findings of this study are not generalisable to other students of the particular university or other universities in Kenya or elsewhere. Rather, the study reported on in this thesis contributes to research on language practices in mathematics education in its own unique context.

Some students in one of the programmes who qualified to be in the sample, with their highest grade in mathematics and their lowest in English, did not give consent to video coverage and/or the use of the data for future educational purposes. This limited the selection of students who had a considerable difference in grades for these two subjects. In order to overcome this, I selected students who had one grade higher in English for that programme than the other two groups (see section 5.3.2.1). In another instance, one of the selected participants did not arrive for the interviews. This was occasioned by some domestic issue. The student was substituted by another who had similar academic scores. The limitation in this case was that I could not tell whether those who were replaced would have provided data that might have resulted in different findings.

The fact that a qualitative case study approach provides in-depth and detailed data has implications for the time spent in collecting the data. Some interview sessions took longer than anticipated. Some participants and one lecturer were not available at either the scheduled or the re-scheduled times. In another case, all the students had rigid academic programmes in place at the time (CATs, lectures, and practical sessions) and also personal issues that prevented them from keeping their appointments. I had to cope with these delays in order to obtain the required data from the selected participants. I re-structured the schedule for data collection and prolonged the period for data collection. The number of interviews per day was increased on some days while on others no interviews were conducted. Eventually more days were needed than had initially been planned.

The data collected for analysis in this study were dependent on students' interview responses and thus sensitive to individual differences. I recognised that not all the participants had responded to the interview (especially the clinical interview) questions as anticipated and thus the data may have been incomplete. This limitation is not unique to this study, since in her work, Planas (2011) reported how learners in her study did not elaborate on issues that she had anticipated the interviews would address. Despite this, she confidently used the available data to draw on students' language identities. In my study, such data were isolated and further some responses were clarified by responses of the reflective interviews. These did not therefore affect the analysis, which was based on patterns formed by sets of data, or the subsequent findings.

5.3.4 Ethical Considerations

Research ethics require that, to gain access to research situations, entry should be negotiated (Hitchcock & Hughes, 1995). I therefore wrote a letter to the administration of the Procity University seeking permission to collect data from the students. In the letter, the intentions, procedures, the target group and the significance of the study were outlined (see Appendix B). The permission was granted in writing (see Appendix C). Subsequently, the College of Science, Engineering and Technology (UNISA) through the College Research Committee (CRC) cleared me to conduct the study. I was obliged to follow the rules and regulations stipulated in the UNISA Research Ethics Policy (see Appendix A).

The target group, first-year undergraduate students in the School of Engineering, were given an information letter describing the purpose, significance and the procedure that would be followed, and their obligations in the study (see e.g. Bogdan & Biklen, 1992; Best & Khan, 1998) (see Appendix B). This was also articulated verbally before the signing of the consent forms. The information accorded them an understanding of the study so that they were able to make their choice of participation freely. They were also assured that withdrawing at any stage of the study would not penalise them in any way.

The participants were informed that the data would be kept confidential and that only my supervisor and I would have access to it, as is advised in research (see Best & Kahn, 1998; Bogdan & Biklen, 1992; Hitchcock & Hughes, 1995). However, the data could be used in conference papers and other academic publications. Their identities would be withheld and pseudonyms would be used in place of their real names (see Appendix H) and that of the university. However, if any one of them wanted his name to be made known they were informed that he would have to make that request in writing. They were also informed that the outcomes of the study would be made available to them by the researcher on request. The findings of the study would be used for educational purposes only, and might be presented in educational forums.

The agreement of the students to participate and the confidentiality of the data were respected in the data collection procedure, in the study write up and will be respected in any future publications. The study held no anticipated risks for the participants.

In inquiry research, researchers need to rely on the findings of other studies to judge the quality of their own research. In other words, researchers need to validate their findings.

5.3.5 Validating this study

Mishler (1990) proposes that since an inquiry-guided research approach posits that meaning and interpretation are socially constructed, the appropriate criterion for judging the quality of an inquiry should be a process of validating and not the application of formal algorithms, as used in traditional experimetal research. Mishler (1990) argues that validation is a process of social construction of knowledge through which qualitative researchers make claims for and evaluate the trustworthiness of reported observations, interpretations and generalisations. The essential criterion for such judgments is the degree to which researchers can rely on the concepts, methods and inferences of a study as the basis for their own theorising and empirical research. If their overall assessment of a study's trustworthiness is high enough for them to act on it, then they are granting the findings a sufficient degree of validity.

This view of validation as a process of social construction of knowledge in the social world suggests that human's construct varied and multiple realities of the world through their discourses and actions (Mishler, 1990). Since the realities change as norms and practices change, the judgment of trustworthiness may change with time even when applied to the 'same' findings, hence altering the validity of these findings (see also Gee, 2005, 2011a). Therefore, validation may be open to disputes and discussions. However, this does not mean that no validation holds. In such situations, validation is guided by accepted realities in the particular domain of inquiry (Gee 2005, 2011a).

By viewing validation as a process, a range of on-going activities through which claims can be made and appraised become necessary (Mishler, 1990). Mishler observes that these activities involve details of research procedures. This suggests that researchers should document and clarify details of the concepts under study, the methods of data collection, full transcripts and video recorded tapes, analysis and inferences made (see, also, Yin, 2003). Furthermore, the challenges that face the study are also necessary for the overall assessment of a study's trustworthiness.

I found Mishler's (1990) process of establishing validation appropriate for my study, partly because this study deals with in-depth inquiry of Discourses, the meanings and interpretations of which the study seeks to understand in the light of Discourse analysis (Gee, 2005). Mishler (1990) has used the concept of exemplars to test validity in narrative studies, and this type of validity is applicable to case studies. In his work on cases studies, Yin (2003) supports validation as a process and suggests that researchers need to document as many steps in the procedures of their case studies as possible.

In this case study of Procity University, I documented a range of steps in the methodology (see 5.3.1–5.3.4 in this chapter). These steps serve to show the trustworthiness of observations, interpretations and generalisation in order to validate the study. The observations are here viewed in the light of pilot study that I conducted, data collection instruments, and procedures, data recording and transcription, all of which are discussed in this thesis. The interpretations are viewed as the sorting of the data into various themes, the analysis and subsequent interpretation of the findings (Chapters 6–10). However, no generalisations were made in this case study, as described in section 5.3.3. Therefore, in the light of the process of validation described by Mishler (1990), the study presented in this thesis can be considered to be validated.

5.4 Conclusion

In this chapter, I outlined the research design and methodology used in the study. I discussed in detail the sampling procedure and data collection procedures. I described the limitations of the study, as well as issues of validation and ethical considerations. In Chapter 6, I explain how I transcribed the data and discuss how this was analysed.

CHAPTER 6

DATA ANALYSIS

6.1 Introduction

In Chapter 5, I discussed how I obtained my data. In this chapter I explain how the data from the pilot study were transcribed and analysed. The analysis drew from the discussion on the theory and methods of Discourse analysis discussed in Chapters 4 and 5 respectively. The chapter concludes with the themes that emerged from this analysis. Based on these themes, the analysis process was then used to analyse selected transcripts in the main study, discussed in Chapters 7, 8 and 9.

6.2 Transcription

To be in a position to analyse the raw data, I needed first to transcribe it. Transcription is a process that attempts to represent actual interactions of research participants' in written text or data (see e.g. Green, Franquiz, and Dixon, 1997 in Tilley, 2003; Setati, 2003). What counts as data to be transcribed is not just what is said but how it is said (Setati, 2003). Furthermore, the data transcribed and the process of transcription is dependent on the purpose of the research. For instance, the research questions, the assumptions of a researcher, the analysis and the interpretation process (see e.g. Gee, 2005, 2011; Lapadat, 2000; Lapadat and Lindsay, 1999; Mishler, 1990; Setati, 2003; Tilley, 2003). Transcribing data for Discourse analysis, as is the case in this thesis, is more elaborate.

In transcribing data for Discourse analysis, Gee (2005, 2011a) suggests that one should consider the bases of this analysis. He observes that the analysis is based on the details of speech (including gaze, gesture and action) or writing that is arguably relevant in the context and to the arguments the analysis is attempting to make. In that sense, Gee (2005, 2011a) notes that what is relevant for transcription is based on the analyst's theoretical judgements that are theories of how language, contexts, and interactions work in general and in the specific context being analysed. Therefore, a transcript is informed by the theoretical framework of the analysis and, in turn, it informs the analysis. For this reason, I was careful about what and how to transcribe the data so that the transcripts would inform my analysis, findings and conclusions, and uphold validity of my study (see e.g. Gee, 2005, 2011a; Mishler, 1990; Setati, 2003).

I selected what to transcribe based on what was meaningful in terms of the research questions (see sections 1.3 & 5.1), my assumptions, and considerations of Discourse analysis (see Chapter 4). Specifically, my transcripts represent what I counted as necessary in what was uttered and how it was uttered, including gestures and actions, in an attempt to address whether, how and why the trilingual students used their languages when engaging with mathematics tasks. This was achieved by listening and viewing the video recordings of all interviews, and was enriched by the field notes. Some of the background information on the participating students gathered from the questionnaires also improved my understanding of the students' utterances. The transcription conventions I used in the transcription process are explained below.

6.2.1 Transcription conventions

Transcription conventions ensure consistency between and within transcriptions (Hitchcock & Hughes, 1995) and allow for their interpretation (Tilley & Powick, 2002). For example, when an utterance is said with emphasis, it can be represented by the use of capitalised or words in bold (Gee, 2005, 2011a). While conventions can be developed for every transcription, Lapadat and Lindsay (1999) note that there are sets of transcription conventions available to transcribers. In using transcription conventions, Lapadat and Lindsay (ibid) advise that transcribers should support how they use them. Since this study is concerned with how language is used in mathematics, I chose and followed conventions that are commonly used by transcribers of data that are language related, for example Gee (2005), and particularly in mathematics, such as Barwell (2003). In addition, I customised some of the conventions for this particular study. For example, I chose / and // to represent short pauses (< 5 seconds) and long pauses (>5 seconds) respectively. Other conventions used are as shown in Table 6.1 below.

Table 6.1 List of Transcription Convections used in this study

Symbol	**Meaning**
PS1, PS2, PS3, PS4	Students in pilot study
S1, S2,...,S15	Selected students in the main study
R	Researcher
/	Short pause < 5secs
//	Long pause >5secs
…	Incomplete statement
[…]	Translations
{...}	My interpretation
(...)	For all others, e.g. mathematical statements as used by students
Bold and italicised letters e.g. ***a, b, x, y, n, k***	Variables used by students in the task

6.2.2 The process of transcribing and the data

All data from both the clinical and reflective interviews with the 15 students selected were transcribed. As highlighted in Chapter 5, section 5.3.2.3, the clinical interviews were transcribed first since they provided guidelines on the questions that would be asked in the reflective interviews. The transcriptions of both interviews were, however, done in a similar way with an eye to the aspects considered important in this study.

In transcribing, I listened for different languages, (either used throughout or switched between utterances), pauses, emphasis and even incomplete statements. I viewed actions and gestures used in tandem with the verbal utterances; to do so I rewound the video several times to capture the essence of what was being said and done. I also took note of students' written worksheets.

Utterances that were in languages other than English were transcribed in the particular language and later translated. This was because every language has its own characteristic mode of meaning for particular things (Halliday, 1974 in UNESCO, 1974). Furthermore, Setati (2003) advises that multilingual data should be transcribed before being translated. As a native speaker of Kikuyu and my proficiency in Kiswahili, I was able to translate utterances in these two languages. In the case of languages in which I understood little such as Dholuo and Luluhya, I collaborated with language translators. By transcribing in the actual language in which utterances were made and later translating them into English, allowed me to capture the meanings intended by the participants. In the transcription, translations are indicated in square brackets. Data that involved pauses, incomplete statements, actions and gestures were represented using the respective transcription conventions indicated in Table 6.1 above.

After completing each transcription, I checked what I had transcribed. The transcripts were dependent on students' verbal reporting and hence accuracy in transcribing was of the utmost importance. I reviewed each transcript, checking for errors and misrepresentations. This was achieved by listening to the verbal utterances and viewing the video several times and comparing this with the transcripts. In doing so, I became aware of some utterances and actions that I had previously not identified; for example, some actions that accompanied verbal utterances. In order to ensure accuracy, I sent the transcripts to the participants to check the accuracy of their utterances. The participants mostly confirmed that the transcripts reflected their utterances correctly, but they also highlighted errors that I subsequently corrected (see selected transcripts in Appendix I).

6.2.2.1 Transcription: not a straightforward process

There were difficulties in transcribing; I hereby highlight those that could have affected the accuracy of the transcripts. Transcribing the clinical interviews was most challenging. In my view this was because it involved the participants' thinking, interpreting, writing and explaining simultaneously. As such, some utterances were inaudible, and I was not sure that they were meant for my hearing or only for the student, as in "private speech" (Vygotsky, 1978) or "talking for myself" (Pimm, 1987). Furthermore, some of the written work differed from what the participants had said. In such cases I transcribed what made sense, based on the previous and later utterances (see Gee, 2005) and by referring to the students' worksheets. I also found that it was difficult to identify how much of the verbal and non-verbal utterances to include in the transcripts. In this regard, I made the decision to transcribe the most relevant utterances, noting the actions and gestures and preserving the written work as it was. Thus, apart from the transcripts, a sample of students' worksheets is provided for reference (see Appendix K). Overall, selecting what to transcribe and how much was sufficient for my transcripts considering my transcription purposes, was not a straightforward process.

I spent a great deal of time transcribing, and the process was particularly tiresome. However, the time spent also provided me with an opportunity to familiarise myself with the data (see Hitchcock & Hughes, 1995) and to understand the data to a degree prior to the main analysis (see Lapadat & Lindsay, 1999). In this way I was able to understand, in part, the participants' interactions that had initially aroused my interest in the study. In total, I transcribed 30 interviews, 15 for each clinical and reflective interview. As it is with characteristic with qualitative studies, the data in my transcripts were voluminous (Creswell, 1994, 2009). Below I describe the transcripts.

6.2.2.2 The transcripts

The data from the clinical and reflective interviews had specific and different purposes in this study, as discussed in section 5.3.1.2. The transcripts of the clinical interviews covered the solution process of the algebraic mathematical task by the students. These transcripts included data on how the students explicitly used languages in tandem (or not) with actions and gestures. The transcripts of the reflective interviews included the different functions of the languages used within the task and other settings such as classroom and examination. Data on how the participants connected the information in the task to other knowledge and different settings was also captured in these transcripts.

For each transcript, I numbered the utterances in turns of utterances of each participant and the researcher. For analysis purposes I selected chunks of utterances that displayed Discourse features and possible meanings that were important for particular analysis (Gee, 2005). I referred to the chunks as extracts and organised them as my units of analysis. I took note of the languages that students engaged with and a summary of the languages they used is presented in Table 6.2 below.

Table 6.2 Summary of languages used by the students

Languages	One language (English)	Two languages (English and home language)	Three languages (English, home language and Kiswahili)
Students	S2, S9 & S11	S1, S3, S4, S5, S6, S7, S8, S10, S12,& S15	S13 & S14

From the 15 paired transcripts[26], 11 were selected because they contained relevant details, rich in both quantity and quality, which would facilitate responses to my research questions, the intended analysis and interpretation, and would validate this study. These 11 were distributed as follows: English only S2, S9 and S11, English and home language S3, S4, S6, S8, S10 and S15, and English, home language and Kiswahili S13 and S14.

In concluding this section on transcription, it is my view that my process of transcription, what I transcribed and how well the transcripts worked together with other elements of the research in part contributed to the validity of the study. The transcripts needed to be turned into evidence, that is, to be analysed to support my arguments in this study. Before embarking on any analysis, Hofstee (2006) advises that one explains what and how he/she will analyse the data. For this purpose I used data from my pilot study to explain my analysis procedures.

6.3 The Process of Analysis

For analysis, I have used the methods of Discourse analysis (Gee, 2005, 2011a) as outlined in Chapter 4, section 4.4. Gee advises "beginners" who are pursuing their first Discourse analysis to pick a piece of data that will both interest the analyst, and that he/she believes will speak to or illuminate an important issue or question that he/she has chosen to address. He proposes that we can do Discourse analysis by first identifying the grammatical cues and clues in a social language. Then one should ask certain questions, guided by research questions or the theme one started with, about the seven building tasks. One should take note and reflect on the answers to the questions, paying particular attention to where answers to several different questions seem to converge at the same point or theme. The points or themes that emerge should then be linked to the theme or question one started with. The analysis should then be organised so that the material one

[26] Paired transcripts here refer to the clinical and reflective interview transcripts of each student.

has developed speaks to, argues for, and illuminates the final main point(s) or theme that one has chosen to address in one's work. I followed Gee's method of analysis, applying what worked for my analysis.

As a mathematics educator pursuing the first study in which I had used Discourse analysis, I chose one student's transcripts of both clinical and reflective interviews from my pilot study for my initial analysis. Analysis of clinical interview transcripts helped to establish how the students engaged explicitly with mathematics Discourse practices and how they drew explicitly on their trilingual language facility, other resources and practices in responding to the task. The analysis of the data from the clinical interview could not, however, inform my analysis of other languages that the students used implicitly, for example in thinking, and could not explain some actions, writing or gestures that the students were involved in. In order to fill this gap, I drew on transcripts from the reflective interviews, the analysis of which facilitated an in-depth understanding of other languages that were used, how and why they were used, and explained actions, gestures and writing. How the participants connected the information in the task to other knowledge and different settings was also evident from this second analysis. The analyses of the two interviews were not isolated; rather, reflective interview transcripts supported or brought in issues that had not been explicit in the clinical interviews.

In addition, in the analysis process I paid attention to interpretation of the task and the solution process. This focus on interpretation of the task was based on the fact that literature (e.g. De Courcy & Burston, 2000; Mestre, 1988) shows that those bi/multilingual students for whom the home language is not the LoLT, often face difficulties when interpreting and understanding the task (see section 2.3.2). The solution process was important because the students had learnt and were learning algebra at the time of data collection.

In the light of my research questions, I posed some key questions to the students during the interviews. From their responses, I extracted the utterances that illuminated responses to my questions. The questions[27] and the general expectations of the responses are outlined in the Table 6.3 below.

Table 6.3 Key questions posed during the interviews and expectations from the responses

Research question	**Key interview question**	**Expectation from the question**
1. How do some trilingual undergraduate students in Kenya use their languages when solving mathematics?	i. What does the question require of you?	Explanation of each student's understanding and interpretation of the task.
	ii. How do you solve the question?	Explanation and justification of each step as they completed the task and writing out their workings.
2. What language practices do these undergraduate trilingual students use when engaging with given mathematics tasks?	i. When you first read the question, what impression did you get? Or other question that was relevant based on student' prior responses. ii. The question was written in English; which other languages did you use as you engaged with the task? (Here utterances in which the students' code switched were central. Since all students had indicated that they wanted to be interviewed in English, then all instances in which a different language was used were taken to be instances of code switching). iii. Which other languages do you use while engaging with mathematics either in discussion groups or alone?	The responses were expected to be illuminated by both verbal language and non-language utterances that they used while solving the task and during reflective interview. Response for question (iii) was either from the reflective interviews or questionnaire or both.
3. Why do these students use their languages as they do?	Why did you use the language(s)?	A range of reasons were expected from reflective interviews transcripts.

[27] The research questions are numbered 1–4 while the key interview questions for the research questions are in Roman numerals.

Using these questions, I structured my analysis according to three main phases:

1. Identifying the grammatical cues and clues in the social languages of students' responses to the algebraic task and in their reflections.
2. Identifying some key word(s) or phrase(s) or action(s) in the social languages and looking at the situated meanings these had. In order to make sense of the situated meanings, I selected the patterns of features in the particular context and that implicated the Discourse models at play.
3. Explaining the different Discourses that the students seemed to enact through the social languages, situated meanings and Discourse models.

This process of analysis was not linear as may be implied by the steps followed. In actual fact, each phase was linked to the other and the process involved back and forth movements. In analysing, I took note that Discourse analysis does not explicitly apply to mathematics education. Therefore, I referred to works that have used Discourse analysis to analyse both language and mathematics learning (e.g. Moschkovich, 2002) (see Chapter 4, section 4.3.2.2).

In the following section, I describe and present the template that I used for the first phase of analysis – that of identifying grammatical cues and clues.

6.3.1 Identifying grammatical cues and clues in students' utterances

I identified the grammatical cues and clues in students' social language from the clinical interview transcripts. As mentioned in Chapter 5 section 5.3.2.3, during the clinical interviews, each participant first read the task on his or her own, and then I asked him or her to read it aloud. Once students had indicated that they were ready to proceed, I asked them to interpret the question and then proceed in solving it. I asked them two key questions pertaining to interpretation and solving the task, as in Table 6.3 above.

1. What does the question require of you?

2. How do you solve the task?

In order to analyse students' response for cues and clues, I drew the relevant aspects of analysis from Table 4.1 and came up with a template for analysis presented in Table 6.4 below. For each Discourse situation, I quoted the relevant utterances from the selected transcripts. I then identified key words/phrases/actions and discussed the indicators under the relevant Discourse situation and tools of enquiry, as outlined in Chapter 4.

Table 6.4 Template for analysis of grammatical cues and clues

Students' utterances	**Discourse situation**	**Keywords/phrases/ actions**	**Indicators of patterns of cues and clues in the utterances of the social language(s)**
	Significance		
	Activities		
	Identities		
	Relationship		
	Politics		
	Connections		
	Sign systems and knowledge		

For question 1 and 2 above, I examined the students' utterances in the light of the Discourse situations by identifying the cues and clues in their utterances. That is, I identified what each of their utterances seemed to make significant, the activities the student was involved in at that particular time, the identity he was enacting, the relationship that his utterances seemed to build, the connections he was making either within the particular context or with previous knowledge, and the sign systems and various ways of knowing that were in operation.

Using the data of one student from the pilot study, I now demonstrate what and how I analysed, highlighting what I looked for in the process of analysis. While I had transcribed all data for the four pilot study participants[28], for analysis purposes I selected the paired transcripts of PS4 because these were rich in quality and details and hence could illustrate most of what I analysed in the main study. I analysed PS4's utterances in response to the question on interpretation of the task[29] using the template in Table 6.4 above. Before explaining the analysis, I provide PS4's background information.

Identifying and explaining cues and clues from PS4's response in the interpretation of the task

PS4 is a 20-year-old male student. His first and home language is Kikuyu. In mathematics engagement he uses Kiswahili and English in most instances. In KCSE he scored Grade A in mathematics and Grade B in English. He was enrolled for the degree of Bachelor of Science in Statistics.

When PS4 was presented with the task (see section 5.3.2.2), he read it on his own, read it aloud and then proceeded to explain what the question required of him as he wrote and sketched:

Extract 6.1

> PS4: Ok. {he reads the first sentence again} When chairs are arranged in rows, {sketching horizontal lines and an outer rectangular frame}), that is our hall. The chairs are arranged in rows {pointing to the horizontal lines, continues reading the question and then subdivides the first horizontal line into parts}, they have the same number of chairs, let's call it ***n*** {writes ***n*** at the end}.

Figure 6.1 presents PS4's sketch of hall and Table 6.5 below his brief analysis of the utterance followed by a discussion on the same.

[28] The students in the pilot study were referred to as PS1, PS2, PS3 and PS4.This was to conceal their identities.

[29] Because of the lack of space in the table, the student's utterances are not presented in the table; rather they are presented as extracts. This also applies in the analysis in the main study.

Figure 6.1: PS4's sketch of a hall

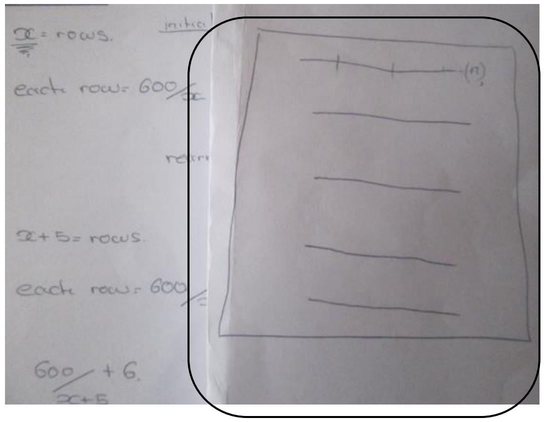


Table 6.5 Analysis of PS4's utterances in the interpretation of the task

Discourse situation	**Keywords/phrase/actions in the utterances**	**Indicators of patterns of cues and clues in the response**
Significance	{sketching horizontal lines and an outer rectangular frame}, that is our hall/ { … and then subdivides the first horizontal line into parts}	He sketches a representation of the hall and he refers to it and improves the sketch, by segmenting the horizontal lines.
Activities	{sketching horizontal lines and an outer rectangular frame} /let's call it ***n***	Sketching and making an assumption
Identities	that is our hall/ let's call ***n***	He uses "our" and "let's"
Relationship	that is our hall/ let's call ***n***	He uses "our" and "let's",
Politics	{sketching horizontal lines and an outer rectangular frame}, that is our hall	A sketch and sketching are social goods worth having/doing for him to interpret the question.
Connections	{sketching horizontal lines and an outer rectangular frame}, that is our hall. {,… and then subdivides the first horizontal line into parts}/let's call it ***n***	He is connecting the task to valued mathematical representation and the unknown values to an assumed value
Sign systems and knowledge	{sketching horizontal lines and an outer rectangular frame}, that is our hall	He represents the hall by sketching it. He uses verbal language and non-language resources and formal mathematics language in making an assumption.

Significance: PS4 made sketching of the hall significant by sketching it out before writing anything else within the task. Starting with some horizontal lines, he drew a rectangular figure all round and then said "that is our hall". Here the horizontal lines represented the rows. He further segmented the rows to show the position of the chairs. Sketching was further emphasised during the reflective interview. In response to why he thought of sketching, PS4 said;

Extract 6.2

> PS4: Ok, you see when you draw, not only in algebra but in most questions**;** let's say it's hard to work out the question if you haven't pictured what it is about. You have first of all to picture it what it's about then from there you see the concentration of that question, will be based on what you drew and from there you can you, you can be able to relate well with the question.

PS4 related visualisation of the task expectations, its representation and interpretation in a rather complex way. He said what one visualises about a question is supported by the drawing one makes about it, which consequently informs the task expectation or interpretation. This positions PS4 as a student who interprets tasks first by imagining and then sketching and then writing out the workings.

Activity: By making the sketch of a hall, he enacted the activity of drawing a representation of a hall in a rectangular shape in more or less the same way that school halls in Kenya are built. Furthermore, he makes an assumption "let's call [it] ***n***" using formal mathematics language. Making assumptions is a practice that counts as participation in competent mathematical Discourse (Moschkovich, 2002) and therefore it could be expected of competent mathematics students. Drawing a representation of the hall and making an assumption identifies PS4 as a student who draws on competent mathematical Discourse practices.

Identities: After sketching, he refers to the sketched hall as "our hall" and later uses "let's" in making an assumption. This is in keeping with the use of the impersonal pronoun “we”. Mathematics textbooks and mathematicians traditionally use “we” in an attempt to move away from the individual mathematician to a more general perspective of a mathematics community (Pimm, 1987). In addition, the student’s approach to the task is similar to how things are done in mathematics Discourse. By making reference to “our” and “let’s” and his approach to the task, PS4 was recognised as a student whose identity was generalised, which is a reflection of what mathematicians do. His identity throughout the extract was stable.

Relationship: Following PS4’s enactment of general identity and stating assumptions as mathematicians do, a general relationship with other mathematicians is established. This relationship is sustained throughout the extract.

Politics: He finds it worthwhile to sketch and hence the sketch and the process of sketching become social goods worth having for him to interpret the question. Drawing is not unique to this question; rather, it seems to be the norm as he indicated in Extract 6.2 above. PS4 built a perspective that sketching and reference to the sketch was necessary for him to relate and interpret the task and then to write it out.

Connections: In his interpretation, PS4 made two recognisable connections. First, he connected the hall in the task to an imagined hall, representing it in a rectangular figure, which is a mathematical representation. Mathematical representations are valued discursive practices in mathematics Discourse (Moschkovich, 2002). Combining verbal explanation with the sketch revealed an elaborate interpretation. Secondly, he connected the unknown value to an assumed value. Thus PS4 combined and integrated verbal interpretation with sketching, which are valued mathematical Discourse practices. These connections position him as a student who is able to link the interpretation of the task to valued mathematics Discourse practices.

Sign Systems and knowledge: As noted in the activity Discourse situation earlier, PS4 privileged formal mathematical language in his interpretation. He in fact used English only in the verbal utterances. I wondered whether English was the only language this trilingual student interacted with while working on the task.

Extract 6.3

R	... Again when you read the question, you read it in English, was there any other language that came into play when you were doing the question?
PS4**:**	Yeah, I read it in English but translating it, I did in Kiswahili.
R:	And then you … when did you come back to English?
PS4:	That is when I was discussing with you. If I was left alone I usually write a question then I speak to myself like; saa naanza kusema hapa niko na two rows hapa na two rows itakuwa aje hapa? [Now I start saying, I have two rows, how will it be?] You see? That language more suits me and it's easier for me to understand the question thus making it simple to do the question.
R:	What if the question is given to you in Kiswa…? *{PS4 interjected}.*
PS4:	That is very difficult instance … because in Kiswahili you see I have ever been given a question in Kiswahili and it's not as easy as it looks. You see I am using my own words … . My own words that I know in Kiswahili to rephrase as it's called, *ni kama* [it's like] social Kiswahili. It is not written. Written and social are two very different things.

Extract 6.3 indicates that PS4 did not explicitly use Kiswahili in the interpretation of the task. However, through the reflective interview, information on its use and how it was used became apparent. PS4 revealed that when he was working alone, he "usually" switched by translating mathematical tasks into Kiswahili. While he is a Kikuyu home language speaker, he used Kiswahili in his translations. This is because, as he says, it was easier for him to understand the question when he translated it into Kiswahili than in either Kikuyu or English. Therefore, he privileged Kiswahili for translating and English for communicating his understanding verbally and in writing. However, he would not be comfortable with mathematics tasks presented in Kiswahili. He argued that the Kiswahili he used in translation was at his own level, where he constructed his own

sentences. This could mean everyday Kiswahili. Of course, if mathematics is presented in Kiswahili, it would be at the level of standard Kiswahili in mathematics, similar to mathematical English.

From the analysis of PS4's utterances in Extract 6.1, it was observed that he used verbal language in tandem with non-language "stuff" to communicate his interpretation of the task. He switched between English and Kiswahili, but only English was verbalised. The non-language "stuff" included a sketch and a communicative system of sketching the hall. Furthermore, in an attempt to clarify his understanding of the hall, he made reference to the sketch. He positioned himself as working with other members of the mathematics community while referring to the sketch and making the assumption. Both statements of assumptions and representations reflect mathematical Discourse practices valued in the mathematics Discourse community. Combining both the verbal utterances and the representation, PS4 was recognised as a student who in interpreting the task, participated in valued mathematical Discourse practices. Therefore, PS4's utterances contained cues and clues to formal mathematical language, generalisation, valued mathematical Discourse practices, and code switching, which in this case was an internal process.

In this section, I explained how I identified cues and clues in one student's response to his interpretation of the task. I also discussed the indicators in the seven Discourse situations. Gee (2005) notes that not all Discourse situations are readily apparent in all pieces of data. As such, some questions in particular Discourse situations may not be relevant or may not yield illuminating answers in the data one has selected. In Extract 6.1 above, most of the questions were relevant and illuminated the research questions in varying and sometimes similar ways. However, this was not always the case in the analysis in the main study.

Having analysed the utterances in the interpretation process, I analysed the utterances of the solution process in the same way. While the analysis of the solution process of PS4 is not presented here, the illustration above also serves to show how I analysed the solution process in the main study. Then I looked for the situated meanings of some of the key words that PS4 used in the social language reflected in the extract and the Discourse models that explained the meanings attributed to the key words/phrases/actions.

6.3.2 Situated meanings of some key words/phrases/actions in the social languages

I used the cues and clues in the utterances to assemble the situated meaning of the words/phrases/actions that were important to interpreting the task. Gee (2005) notes that some of the situated meanings to be considered are those attached to places, times, bodies, people, objects, artefacts and institutions relevant to a given situation. I took note of what Gee (1999) says about words and phrases; that they have multiple and ever-changing meanings created and adapted to specific contexts of use. At the same time the meanings are integrally linked to social and cultural groups in ways that transcend individuals (Gee, 1999). Therefore, I looked at the meanings of words, phrases and actions that the students attributed to them and not what they meant to me. Furthermore, and as stated earlier in this chapter, I used a situated-sociocultural perspective which assumes that participants bring multiple views to a situation and that representations have multiple meanings for participants and that these multiple meanings for representation and inscriptions are negotiated through conversations (Moschkovich 2002). In order to understand the situated meanings of the words/phrases/actions, I looked at the Discourse models that were at play at the time. In order to achieve this, I was guided by questions 1–3 on situated meanings and Discourse models that are suggested by Gee (2005: 110–111) as stated in Chapter 4 (section 4.4).

The word "hall" seemed to be important in the task situation for PS4; in fact, he sketched a representation of what he referred to as "our hall". Hence it was imperative to understand his situated meaning of a hall in this particular context. By referring only to his workings, one could interpret a hall as any one of a range of formal and dictionary meanings. However for PS4, there was a situated meaning to "hall". He explained this during the reflective interview:

Extract 6.4

> PS4: Ok, (a hall is) like a theatre, I thought of a theatre because they say there is fixed number of rows, right? … and in a theatre is where you find that chairs are fixed you cannot think of a hall like a … a school hall because you know a school hall, chairs are either forms or … you have to associate with a kind like a theatre.

Extract 6.4 shows that his first concept of a hall was as a theatre. Why does he view it as a theatre? His experience informed his view. According to PS4, in a theatre chairs are fixed as opposed to in a school hall, which is furnished with forms or benches. This argument was based on the social and cultural background to which he belonged. PS4 had recently graduated from a boarding secondary school and he therefore had good experience of school halls such as dining halls and church halls. In some Kenyan schools contexts these are furnished with benches and not chairs. In addition, he may have had experience of the arrangement of chairs in a theatre because secondary school students commonly visit theatres to watch performances of their literature set books. Given his experiences with halls, PS4 simulated the hall in the question in terms of a theatre rather than a school hall in order to make sense of the task. In this particular case he took a theatre to be a "normal" hall and a school hall to be "non-normal". PS4's Discourse models of a hall guided him in situating the meaning of the hall in the particular case. While he viewed the hall as a theatre with fixed chairs, the problem did not indicate that the chairs were fixed. However, it is interesting to note that imagining fixed chairs in his mind helped him to interpret the question at the time.

In the study reported here, I used a similar approach to analyse the situated meanings and Discourse models that the students enacted.

6.3.3 Discourses enacted

I identified the Discourses that the participants enacted by drawing from the social languages, situated meanings, and Discourse models that were at play. For this purpose, I addressed questions 4–5 stated in Chapter 4 (section 4.4).

PS4 combined and integrated verbal utterances with his ways of thinking and using mathematical artefacts. Furthermore, his way of imagining, visualising, making mathematical connections and assumptions resonates with participation in competent mathematical Discourse (see Moschkovich, 2002). This trilingual student switched mentally between English and Kiswahili while interpreting the task; these were the languages that he commonly used in mathematics peer discussion groups. PS4 therefore "pulled off" the Discourse of a student who participated in competent mathematical Discourse, verbalising his utterances in English while also engaging Kiswahili in his internal communication.

I followed the process described above to analyse whether, how and why each of the 11 student participants whose transcripts were selected for analysis used language in solving the question. As described in Chapter 5 (section 5.2.1), each student was regarded as a single case. For each case, I conducted an in-depth analysis. This provided me with some understanding of the students' language practices through the analysis of processes, meanings and understandings gained from their words, written work, actions and gestures. Collectively, the cases yielded rich findings. Through the process of analysis, I recognised the socially situated activities and identities that the students had engaged with as they interpreted and solved the task. It should be noted here that the transcripts of the reflective interviews were mainly used to support or confirm critical issues and moments that were noted during the clinical interviews. As such, how the students used language in the reflective interviews was not analysed independently.

Among the 11 transcripts selected for analysis, six students switched between two languages, English and their home languages. The home languages were Kiswahili and several other indigenous languages. All six code switched mentally, that is, in their thought process. Two students switched between English, Kiswahili and their respective home languages. These students switched to Kiswahili explicitly and to their home languages internally. Three other students indicated that they had not switched at all when engaging with the task. The students used language to position themselves in mathematics Discourse in their own unique ways. After the analysis of all 11 transcripts, three main themes emerged.

6.4 Themes

A common thread in the analysis was that these students switched between English and other languages as they engaged with the task. Exceptional to this was using English only. Thus the following themes emerged:

1. Language practices involving English only
2. Language practices involving two languages: English and home language
3. Language practices involving three languages; English, Kiswahili and home language

6.5 Conclusion

In this chapter I explained the transcription of the data and the process of analysis followed. The analysis of students’ utterances when they engaged with the task, during the clinical interviews, were supported by explanations from either or both the reflective interviews and the questionnaires. The themes that emerged were then used as the basis for the analysis of 11 transcripts in the main study. This is discussed in the following three chapters.

CHAPTER 7

LANGUAGE PRACTICES INVOLVING ENGLISH ONLY

7.1 Introduction

In this chapter, analyses of language practices of three trilingual undergraduate students who used English only are presented. English, the LoLT, was the language in which the task was presented. The analysis used the methods of Discourse analysis as illustrated in Chapter 6 (section 6.3). I begin the Chapter with a brief recap of some key issues that are critical to the analysis. In the remainder of the chapter, the language practices of the three trilingual students and the discussion of these are presented.

7.2 Recap

The language in education policy was explained in Chapter 1, section 1.5.1.1, where I explained that the official languages of Kenya are English and Kiswahili. It was noted that while the trilingual students are exposed to Kiswahili and home languages during sometime in their schooling, there is a monolingual LoLT policy at university level.

Literature reviewed in Chapter 2 (section 2.2) shows that while students need to gain control of the mathematics register (e.g. Pimm, 1987) and use the valued formal mathematics language (Setati & Adler, 2000), it is the mathematics Discourses within their communication that are most important in deriving meaning from their utterances (Moschkovich, 2002). The ways of participating in mathematical Discourse include the use of technical terms from the mathematics register, formal mathematics language, ways of talking, thinking, interacting, writing, mathematical values and points of view of a situation (Chapter 4, section 4.3.2.2). Students may also gesture or make sketches to communicate their ideas. They can communicate these Discourse practices in the LoLT, in their home language or in the national language, or they can switch between all the languages. For trilingual speakers, switching between any two languages is an important speech strategy (Chapter 3 section 3.4). They assign, consciously or not, different functions to their three languages (Hoffmann, 2001). In the light of Hoffmann's observations, I explored how and why some trilingual undergraduate students in Kenya used one, two or three languages when they engaged with mathematics.

The analysis process in this study focused on the transcripts of the clinical interviews (see Chapter 6, section 6.3). These interviews covered the interpretation and solution process of the algebraic task by students. Data from transcripts of reflective interviews was used to support or bring out issues that were not explicit during the clinical interviews. During the interviews I posed some key questions to the students as in Table 6.2.

As Hoffmann (2001) has observed, trilingual students may use one language in their engagements. In what follows I analyse the data for language practices of trilingual students who depicted a monolingual language practice. Prior to the analysis of each transcript, a brief background to the student is provided so as to understand his linguistic and academic background.

7.3 Engaging with mathematics in English only

The language practices of S2, S9 and S11 were in English only. A detailed analysis of the language practices of S2 is presented, as well as a brief analysis of the language practices of both S11 and S9. This is because an analysis of the cues and clues in the social languages of S11 and S9 were typical of those of S2; hence they are not repeated here. The reasons for the students using English only are discussed. This analysis revealed no instances of code switching in either verbal explanation or in mental engagement with the task. The students used language in the same way as monolinguals.

7.3.1 Analysis of S2 utterances

S2 was a Kikuyu language speaker. His home language was Kikuyu, the language through which he commonly interacted with his family, making little use of either Kiswahili or English. In his engagement with mathematics, he used both English and Kiswahili equally with himself and when among his peers and lecturers. He scored Grade A in mathematics and B- in English. He was enrolled for a degree in Geomatic Engineering and Geospatial Information Systems. While S2 indicated that he switched between codes in the questionnaire, his language use was rather different in the given task.

7.3.1.1 Identifying and explaining cues and clues

a. In the interpretation

S2 read the task and then worked it out silently for a period of about 13 minutes. When he had finished, he explained what the task required of him from his written work. While he explained the whole working, I present here the first part only of his explanation of what I considered to be the interpretation part of the task.

Extract 7.1

> S2: So let the number of rows to be $\boldsymbol{x}$**,** the total number of rows {gestures with his hand to indicate the arrangement of rows horizontally} has a total of 600 chairs. Then we are told that the chairs were rearranged meaning that, after rearrangement the rows will increase by 5, so I take ($\boldsymbol{x}$+5), but the number of chairs per row is decreased by 6, so I have come to say that let the number of chairs be $\boldsymbol{y}$ in each row, so in each row there will be a decrement of 6 chairs after the rearrangement. So I have come to say that the number of chairs per row will be 600/$\boldsymbol{x}$. Then after the rearrangement it will be 600/($\boldsymbol{x}$ + 5).

Table 7.1 below reflects how S2 used language while interpreting the task in Extract 7.1.

Table 7.1 Analysis of S2's utterances in the interpretation

Discourse situation	**Key word/phrase/actions**	**Indicators of patterns of cues and clues in the response**
Significance	{gestures with his hand to indicate the arrangement of rows horizontally}	He describes the arrangement of rows making it significant by gesturing with his hands.
Activity	so let the number of rows to be ***x*/** {gestures with his hand to indicate the arrangement of rows horizontally}/ let the number of chairs be ***y***	He is making assumptions and indicating the arrangement of rows with a gesture.
Identity	we are told/ I take (***x***+5)/ so I have come to say/ So I have come	He uses "we" when referring to the information given in the task and to "I" when referring to his written work. He is identifying with the mathematics Discourse community.
Relationship	we are told/ I take (***x***+5)/ so I have come to say/ So I have come	He relates with other members of mathematics Discourse community when reading the task but detaches himself when doing the task.
Connections	let the number of rows to be ***x*** /let the number of chairs be ***y*** in each row	In order to make assumptions, he uses terms used in mathematics register.
Sign system and knowledge	So let the number of rows to be ***x*…**Then after the rearrangement it will be 600/(***x*** + 5).	He uses English throughout the utterance.

Significance: S2 made gesturing significant in interpreting the task. He indicated the arrangement of rows using gestures. He also made the use of formulae significant, as was captured when he explained his impression of the task during the reflective interview:

Extract 7.2

S2: … Even the first thing I thought, I knew even after reading the question I knew that there will be a quadratic equation. So after I read it fully, at the beginning I had seen as if I would use one of the formulae we use in series and sequences but after reading the whole question I saw that I will involve a quadratic equation so I will use the factor formula, the quadratic formula or the other formula to find the value of ***x*** in quadratic equations.

S2's first thoughts were on the topics of sequence and series and one of the formulae in that area. However, he realised later that it involved the formation of a quadratic equation and hence the need to use the relevant formulae. He was looking for a formula that he could use for either of the topics. Therefore, he made the use of formula significant in this task.

Thus S2 is recognised as a student who made gesturing and the use of formulae significant in interpreting the task.

Activity: He made assumptions about the number of rows and chairs and he also signalled the arrangement of rows in gestures. In his workings, S2 also made a sketch. I enquired about this:

Extract 7.3

R: You drew a figure at one time here {see sketch below}. What did it mean?

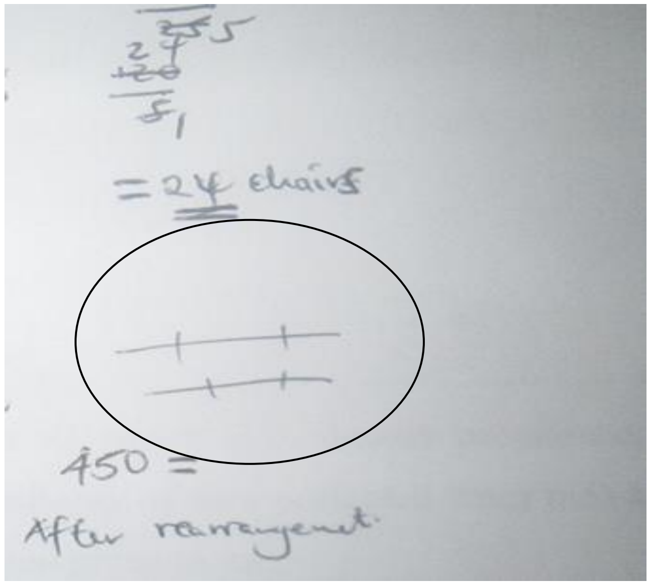
S2: I meant that these chairs in this question we are told that ... I drew this figure to show me that this side there will be equal number of chairs and in this row there will be equal chairs left on this side and on the other side {illustrating with his hand }.

R: And do you do this often with algebraic questions, trying to make some diagrams or sketches?

S2: If a question is involving such, I usually do.

Below is a part of S2's working and the sketch he drew

Figure 7.1: S2's sketch of rows and chairs



The sketch was important for his visualisation of the arrangement of the chairs. He not only sketched in this particular task, but it was a practice that he embraced when similar visualisations seemed necessary. Therefore, S2 was recognised as a student who was involved in the activities of making assumptions, gesturing and sketching, all of which are valued mathematics Discourse practices (Moschkovich, 2002).

Identity: S2 used language to identify himself with mathematics community as well as an individual mathematician (e.g. Pimm, 1987; Rowland, 1999). He initially identified himself with the mathematics community when in reading the task information he used the pronoun "we", later changing to personal involvement when explaining what he had done using "I". This latter identity marked a personal action and ownership of the written work (see Rowland, 1999). In general, his use of pronouns and his approach to interpreting the task identified him with the mathematics Discourse community.

Relationship: S2 talked and acted in ways that suggest that he was building a general and individual relationship with the mathematics Discourse community.

Connections: S2 used language to construct sentences that are used in valued mathematics Discourse practices (Moschkovich, 2002). For instance, "let the number of rows be ***x***". Such constructions are used in the mathematics register and in mathematics Discourses when making assumptions.

Sign system and knowledge

S2 used only English language when explaining his interpretation. As he was trilingual, and he had indicated in the questionnaire that he commonly used Kiswahili together with English when engaging with a mathematics task, during the reflective interview I enquired whether he had used other languages when he engaged with the task:

Extract 7.4

R: The question was written in English. Is there any other language that featured as you responded to the question?

S2: Usually in mathematics when solving problems you can't find a mathematical sum in Kiswahili or Kikuyu, so when I began studying I was taught English[30]. I had to go by that so that I could comprehend what the questions are saying. So if I read in English even in my thinking I will somehow think in English so that I can be able to connect the sentences and even the questions so that I can be able to reach at the answer.

Two reasons for S2 not code switching as he engaged with the task emerged from this conversation. First, the fact that S2 had not found mathematics tasks written in Kiswahili or Kikuyu, was reason enough for him not to switch to either of these two languages. Second, and further from initial stages of learning, he was taught mathematics in English. While the statement "I will somehow think in English" suggests some uncertainty in the language he used when thinking, I understood that since the task was in English, his thinking followed in English so that he could comprehend the task, connect the sentences and be in a position to answer it. This can further be evidenced by the fact he did not switch languages even when he misinterpreted that the task was in

[30] Following this utterance, it can be assumed that S2 attended lower primary school in an urban area. In these areas, English is commonly used as the LoLT (see Cleghorn, Merritt & Abagi, 1989)

sequence and series (see Extract 7.2). He used English throughout, even in the solution process. The fact that S2 used English alone in the task and in other tasks contradicted his earlier claim; he had indicated in the questionnaire that he switched between English and Kiswahili when working on mathematics tasks. While his claim may refer to prior situations where he switched between English and Kiswahili, given his arguments above, it is clear that S2 did not switch languages in the task in this study.

From the analysis of the language practices of S2, it is clear that code switching was not a concern for him. His trilingual language facility did not necessarily imply he would switch between the three languages in his repertoire. He kept to the LoLT and used this language as it is used in mathematics Discourse. S2 proceeded to explain the solution process from his workings:

b. In the solution process

Having formed two simple equations, S2 proceeded to relate them to form one quadratic equation that he solved;

Extract 7.5

S2: By that I have come to form an equation where I have said, $600/(\boldsymbol{x} + 5) = (600/\boldsymbol{x}) - 6$ {the 6 that were removed}. So I have solved it and I have got the number of rows were 20. I have got a positive number, meaning this is the one that I have taken {$\boldsymbol{x} = 20$} because the other one I have got a negative, there is no way you can have negative rows {he had worked out the negative value $\boldsymbol{x} = -25$ and cancelled it out}.

Table 7.2 Analysis of S2's utterances in the solution process

Discourse situation	**Keywords/phrases/ actions**	**Indicators of patterns of cues and clues in the utterances of the social language(s)**
Activities	I have come to form an equation/ I have said, 600/($\boldsymbol{x}$ + 5) = (600/$\boldsymbol{x}$) - 6/ So I have solved it/ I have got a positive number, meaning this is the one that I have taken {...$\boldsymbol{x}$ = 20} because the other one I have got a negative, there is no way you can have negative rows.	He formed a quadratic equation and solved for the variable $\boldsymbol{x}$ it. He differentiated the solutions he got..
Identities	I have come to form an equation/ I have said, 600/($\boldsymbol{x}$ + 5) = (600/$\boldsymbol{x}$) - 6/ I have solved it/ I have got a positive number/ I have taken ($\boldsymbol{x}$ = 20)/ I have got a negative/ no way you can have negative rows.	He commonly used the pronoun "I" and later "you"
Relationship	I have come to form an equation/ I have said, 600/($\boldsymbol{x}$ + 5) = (600/$\boldsymbol{x}$) – 6/ I have solved it/ I have got a positive number / I have taken ($\boldsymbol{x}$=20)/ I have got a negative/ no way you can have negative rows	He established a personal and general relationship with the mathematics Discourse community.
Politics	I have come to form an equation/600/($\boldsymbol{x}$ + 5) = (600/$\boldsymbol{x}$) - 6/ I have solved it/ I have got a positive number / I have taken ($\boldsymbol{x}$ = 20)/ I have got a negative/ no way you can have negative rows.	Formulating a quadratic equation, solving for the variables and choosing the appropriate solution were social goods.
Connections	600/($\boldsymbol{x}$ + 5) = (600/$\boldsymbol{x}$) - 6 /meaning this is the one that I have taken {in reference to $\boldsymbol{x}$= 20} because the other one I have got a negative, there is no way you can have negative rows.	He connected two simple equations and justified why he took the positive value of $\boldsymbol{x}$.
Sign systems and knowledge	I have come to form an equation/ 600/($\boldsymbol{x}$ + 5) = (600/$\boldsymbol{x}$) - 6/ I have solved it/ I have got the number of rows were 20.	Using a single variable, he formed the required quadratic equation.

Activity: S2 engaged with activities with which mathematically competent people engage. This is evident in the way he related the two simple equations that he had formed to form the expected quadratic equation. Using the quadratic formula, he solved for the variable $\boldsymbol{x}$ obtaining two values, $\boldsymbol{x} = 20$ and $\boldsymbol{x} = -25$. He differentiated these solutions based on the expected solution; one cannot have negative rows.

Identity: Rowland (1999) argues that in mathematics "I" is used as a marker of personal action in time and space; furthermore, a speaker may shift from "I" to use "you", which marks a detachment thus making a generalisation. S2 used "I" when explaining the solution process from his written work. By doing so he identified with his previously written work. Later he shifted to "you" to express the fact that the number of rows cannot take a negative value. This implies a generalisation. Therefore, S2 was recognised as a mathematics student who identified with how pronouns are used in mathematics discourse and his approach resonates with how members in mathematics Discourse work out such tasks.

Relationship: His language use and approach to the task positions him both as an individual and as a member of the mathematics Discourse community.

Politics: Students' ability to formulate and solve quadratic equations represents social goods worth having, according to the first year mathematics syllabus of Procity University. S2 formed a quadratic equation by relating the two simple equations he had formed. He then solved it using the quadratic formula and differentiated the solutions and hence indicated that the positive value of $\boldsymbol{x} = 20$ was the number of rows.

Connection: S2 made connections within the task, connecting two simple equations to formulate the required quadratic equation. Furthermore, he justified his choice of the number of rows as positive saying that the number of rows could not be negative. By justifying, he connected his explanation to conceptual mathematics discourse.

Sign systems and knowledge: Although S2 had introduced two variables ($\boldsymbol{x}$ and $\boldsymbol{y}$) in the interpretation; he used a single variable $\boldsymbol{x}$ to formulate the quadratic equation.

Therefore he privileged the one variable method to arrive at the quadratic equation. He also privileged the quadratic formula in solving for the variable $\boldsymbol{x}$. As indicated in the interpretation process, S2 engaged with the task in the English language only.

Discussion

S2 is a student who made gesturing and the use of formulae significant. He was involved in the activities of sketching the arrangement of the rows, making assumptions, formulating the quadratic equation and solving for the variable that he had introduced. Making assumptions, gesturing and in fact sketching, formulating and solving tasks are valued practices in mathematics Discourse (Moschkovich, 2002). He used language to position himself as an individual and as a member of the mathematics Discourse community (Pimm, 1987; Rowland, 1999). This was evident in his use of impersonal pronouns in reading the task information and in making a generalisation on the nature of the value of the number of chairs. He used personal pronouns while explaining from his written work. His approach to the task also positioned him as a student who was competent in mathematics.

This student used English throughout the interpretation and solution process, in his verbal and written explanation, and in his thinking. His use of English helped him to make the necessary connections within the task and to respond to them. He did this because he was first taught mathematics in English and hence his thinking was also done in English. Furthermore, mathematics tasks were presented in the English language only. This resonates with Moschkovich's (1996) description of situations in which bilingual students who have been exposed to mathematics in the LoLT may not switch to their first languages when solving problems. Similarly, some Kirundi-French bilinguals kept to French and did not switch to their first language, Kirundi, because mathematics learning and the application of formulae was conducted predominantly in French (see Ndayipfukamiye, 1994). As in the case of these bilinguals, while S2 was a trilingual student, he did not resort to code switching as he engaged with the task. Given S2's reasons for engaging in English only and the fact that he was unlikely to encounter a mathematics task in a language other than English, he is unlikely to switch between codes as he engages with mathematics in the future.

S2's utterances contained cues and clues to formal mathematics language, mathematics register, conceptual mathematics discourse, valued mathematics Discourse practices, generality and individuality, and the use of the English language only.

7.3.1.2 Situated meaning and the emerging Discourse model

S2 situated the meaning of the hall in the task as a theatre. His explanation was based on his real life experience that one watches films in a theatre. It was in a theatre that he and other high school students commonly watched dramatisations of Kiswahili and English literature set books. He observed that as a member of the audience, one could decide against sitting at the back and move closer to the front. In this regard, the hall could be rearranged. This was consistent with rearrangement in the task. This experience helped him to relate to the task and to solve it. From his explanation, S2 was operating with the Discourse model of a hall as a theatre.

7.3.1.3 Emerging Discourse

From the analysis above, it is evident that S2 combined and integrated language with gestures, formulae, assumptions, sketching and a view of the hall as a theatre in order to solve the task. He assumed a general and individual identity and relationship. Furthermore, he engaged with the task in English only.

7.3.2 Language practices of S11 and S9

The focus of this section is on how these S11 and S9 used English in the interpretation and solution process of the task.

S11 is a 19-year-old Ekegusii first and home language speaker. At home he communicated with family members in Ekegusii, with little use of Kiswahili. He engaged in mathematics with peers and lecturers in different languages: when working alone or with lecturers he switched between English and Kiswahili, but when interacting with his peers, he used Ekegusii, Kiswahili and English. He scored Grade A in mathematics and B in English. He was enrolled for a degree in Civil Engineering.

In this particular task, S11 used English only but if other more demanding questions arose he would use other languages. Prior to the conversation below, he was explaining that as he read the question, he tried to understand and interpret the task. I then enquired whether he might have used other languages in the process.

Extract 7.6

R: When you were interpreting, comprehending … were there other languages that came into play other than English … in which the question was written?

S11: Ok, according to this question, as far as this question is concerned, the language that I had to use to interpret was specifically English, but if there are other questions that become difficult occasionally it may force us to some different language so that you can get exactly what the question requires.

R: So if the question is more demanding … {S11 interjected}

S11: Yes if the question is more demanding and the language that is used cannot be understood, according to me for example, I can interpret it in another language that I can easily understand.

It became clear from this conversation (Extract 7.6 above) that S11 used English throughout the task because it was at a level that he could clearly understand in English. However, if he was presented with tasks that were more demanding and he could not easily understand the language used in them, he could switch to other languages that he understood better. A language that could be understood in this context could mean a language that he could interpret and understand a task in. According to S11, these languages were Kiswahili and Ekegusii, as he explained later. Therefore S11 was recognised as a student who engaged with the task in English only but who was likely to switch between codes if the task was more demanding (than the task at hand) and if he did not fully understand the language used in a task. In this particular task, the need to switch between codes did not arise.

Similarly, S9 indicated that the task at hand was expressed in simple terms that did not require him to switch between codes in order to translate into his home language. However, in tasks that were more demanding he would switch to his home language to check his understanding.

7.4 Findings on language practices involving English only

S2, S11 and S9 used English throughout the given task. S2 did so because, from the initial stages of his education he was taught mathematics in English; furthermore, he had not encountered mathematics tasks in Kiswahili or Kikuyu. While he may have switched between English and Kiswahili in prior situations and in other tasks, it is clear that S2 did not switch languages in this task. Nor was he likely to switch languages as far as tasks presented in English were concerned. S11and S9 used English only because they understood the language used in the task; if the task had been more demanding, they would have switched to a language that better conveyed the meaning of what the task required. Therefore, in my view, while code switching was not practised by any of these three students in the given task, S2 had no recourse to switching between codes while this option was open to S11 and S9.

These findings are consistent with the findings of Clarkson, (2006), Moschkovich (1996), Ndayipfukamiye (1994) and Parvanehnezh and Clarkson (2008), who all found that having two languages in one's repertoire does not mean that bilingual students necessarily switch between languages. The three trilingual students had three languages at their disposal but did not switch between them, at least not in the given task. They used language the way monolinguals do as indicated by Hoffmann, (2001).

7.5 Conclusion

In this chapter, I discussed the analysis of the language practices of students who used English only when engaging with the task. A key finding was that a trilingual student may keep to the LoLT and not switch to his home language when engaging with mathematics because mathematics is taught and presented in English. If the language used in the task is clear to the student and the task is not particularly demanding such a student may also keep to the LoLT. These findings reveal that trilingual students do not necessarily switch between languages in their repertoire when engaging with mathematics.

In the next chapter, I discuss the analysis of the language practices of students who used two languages in the task, the LoLT and their respective home language.

CHAPTER 8

LANGUAGE PRACTICES INVOLVING TWO LANGUAGES

8.1 Introduction

This chapter discusses the analysis of the language practices of six trilingual undergraduate students who switched between the LoLT and their home language when they engaged with a mathematics task. The language practices of these students were identified and explained through the identities and activities that they enacted in their engagement with the given mathematics task, and the findings are discussed.

8.2 Language practices involving English and home language

The students who switched between English and their home languages were S8, S6, S3, S15, S10 and S4. The home languages of these trilingual students were Kiswahili in the case of S8 and S6, while S15 spoke Kikuyu, S10, Kikamba, S3, Luluhya and S4 spoke Dholuo. Code switching practices were evident in their thinking as explained during the reflective interviews and, for some, in their verbal utterances during the reflective interviews. S8, S15, S6 and S10 switched to translate the whole task while S3 and S4 switched to translate parts of the task.

In this chapter, I present a detailed analysis of how S8 and S3 used two languages while I briefly examine the responses of S6, S10 and S15, and S4 respectively. Analysis of the cues and clues in the social languages of S8 and S3 were more informing than, and somewhat typical of, those of S6, S10, S15 and S4. Hence the choice to present in details the analysis of S8 and S3. A further aim of the brief examination was to support the findings on the language practices of S8 and S3 and/or to raise other pertinent issues regarding students’ use of their languages.

8.2.1 Analysis of S8's utterances in the interpretation and solution process

S8 was a 20-year-old student at the time of data collection. His first language was Kikuyu and his home language Kiswahili; that is, at home he commonly used Kiswahili and more rarely Kikuyu. He explained that this language use was the result of the common use of Kiswahili among the linguistically heterogeneous community in Kenya's Rift Valley province where he lived. He commonly used English and Kiswahili to think and with his peers and lecturers. He scored a Grade A in mathematics and Grade B- in English. S8 was pursuing a Bachelor's degree in Mechatronics Engineering.

S8 switched between Kiswahili and English in interpreting the task. While this was not evident in his verbal or written explanation, his reflections show that he switched to Kiswahili in thinking throughout the task.

8.2.1.1 Identifying and explaining cues and clues

a. In the interpretation

S8 first worked on the task silently and then proceeded to explain from his workings. Below is the analysis of his response to "what does the question require of you?"

Extract 8.1

> **S8:** This question, because here we have unknowns, we have kind of like before the rearrangement we know that the hall had a certain number of rows and each row had a certain number of chairs. So you give the number of rows an arbitrary letter like ***a*** like I've done here {pointing where he had written ***a***}. I've said let the number of rows be ***a*** then, before the rearrangement, then I've said that because after the rearrangement the number of rows are increased by 5, so after the rearrangement the number of rows will be (***a***+5) …

Table 8.1 presents a brief analysis of S8's response.

Table 8.1 Analysis of S8's utterances in the interpretation

Discourse Situation	Key words/phrase	Indicators of patterns of cues and clues in the response
Activity	This question, because here we have unknowns… So you give the number of rows an arbitrary letter like ***a/*** then I've said that because after the rearrangement the number of rows are increased by 5, so after the rearrangement the number of rows will be (***a***+5).	S8 is making assumptions and formulating an expression, and giving justifications. First he assumed the number of rows (and chairs) and gave the reason for making the assumptions. Secondly, he explains how he formulated the expression (***a***+5) and justifies it.
Identity	We have unknowns/ we have kind/ we know/ So you give the number of rows an arbitrary letter like ***a*** like I've done here {pointing where he had written ***a***} I've said/ then I've said that because…	S8 uses the pronoun "we" in his explanation, "you" in making an assumption and "I" where he refers to his workings. Furthermore, he is presenting himself as a mathematician as is evident in his words and approach to the task.
Relationship	We have unknowns/ we have kind/ we know/ So you give the number of rows an arbitrary letter like ***a*** like I've done here {pointing where he had written ***a***} I've said/ then I've said that because…	S8 uses the pronoun "we" then shifts to "you" and finally to "I". With the movement from "we", through "you" to "I", he transforms his relationship with the mathematics community to a personal identity.
Politics	This question, because here we have unknowns… So you give the number of rows an arbitrary letter like ***a/*** then … because after the rearrangement the number of rows are increased by 5, so after the rearrangement the number of rows will be (***a***+5)	His ability to make assumptions and to formulate a mathematical expression amount to social goods associated with the first-year algebra mathematics module.
Connections	This question, because here we have unknowns… So you give the number of rows an arbitrary letter like ***a/*** like I've done here {pointing where he had written ***a***}	He is involved in connecting unknowns to arbitrary values within the task and at the same time justifying this connection. By making the justification, he makes connections with conceptual mathematics discourse. S8 also pointed to his written work while explaining. Pointing connected his verbal explanation with his written work.
Sign systems & Knowledge	This question, because here we have unknowns/ So you give the number of rows an arbitrary letter like ***a***	S8 uses the words "unknown" and "arbitrary" which are used while making assumptions in mathematics discourse.

Activity: S8 was involved in making assumptions and formulating an expression, both of which he justified. These are practices that are valued in mathematics Discourse (Moschkovich, 2002). He became aware of making the assumptions before he started reading the question. This he explained as he described his impression of the question during the reflective interview:

Extract 8.2

S8: … the first time I read the question; and even before reading the question I saw it was written "Algebra", so I kind of in my mind I was now prepared for something to do with unknowns and thereafter reading the question I was trying to think about which unknowns I would come up with.

The task was headed with the word "Algebra". From the above extract, it is clear that this word gave him the clue that the task would involve unknown values. This idea of unknowns was confirmed once he read the question. His focus then shifted to the unknowns he could use. In this regard, S8 assigned arbitrary values to the rows and chairs, making assumptions. He justified making these assumptions by the argument that since there were unknowns, then arbitrary values had to be assigned to them in an attempt to solve for the rows and chairs. Similarly, S8 explained how he formulated the expression (***a***+5) and justified the formulation.

S8 gestured to fix a numerical value that was in the task into his mind. He did so when he was working on the task on his own prior to his verbal explanation. He explained that he raised his little finger when he initially read the questions so that he could fix the number six in his mind. From the task, six was the number by which the rows decreased. He explained as follows:

Extract 8.3

R At the start here {plays the video clip} at the very beginning there's an action. Look at that. What was that? {Referring to his action of raising the little finger}

S8: There was something six. There was a six and I was showing the six ... In my mind now I was kind now like when reading the question the first time trying to understand it putting the figures on my mind, hii [this is] five {raising his fist}, hii [this is] six {raising the last finger} so when I do this it will stick. I know I did this {raising his little finger} there was a six somewhere.

While I only noted the raising of the little finger, he had also raised the fist to fix the value five. He claimed that by using such gestures the numbers were fixed in his mind, perhaps supporting his interpretation.

Therefore S8 can be regarded as a student who was involved in the activities of describing and justifying the steps he took, and using gestures to interpret the task.

Identity: In his explanation, S8 referred to "we", later to "you", and in direct reference to his written work, he used the pronoun "I". These pronouns are commonly used in mathematics talk (Rowland, 1999). His use of "we" and "you" suggests a shared understanding of the conditions set out in the task and the unknown variables. In fact, he used formal mathematics language, which serves to show how language is used in mathematics. In using these personal pronouns, S8 engaged with the task the way mathematicians do. Later he moved on to explain how to make the assumptions from his own perspective, which was from his earlier written work. In using "I" he reflects knowledge and ownership of the interpretation process. His use of the pronouns is in keeping with the mathematics register that researchers (see e.g. Pimm, 1987; Rowland, 1999) argue is not entirely impersonal.

As well as using these pronouns, S8 is presenting himself as a mathematician and this is evident in the words he uses and how he approaches the problem. Choosing an arbitrary letter to represent an unknown number, formulating and justifying expressions to define or describe a situation are also some of the things that mathematicians do.

S8 was thus recognised as assuming the identity of a mathematician at once in a general and a personal perspective.

Relationship: the use of the pronouns “we”, then “you” and finally “I” shows that S8 shares his understanding of the task in the same way as other mathematicians and then explains how the task should be performed from his point of view. In doing so, he relates with other mathematicians as a student who approaches the task as ably as other mathematicians while at the same time using words and modes of argument from the mathematics register. Hence he formulates the necessary mathematical expressions. In this way his relationship with other mathematicians changes from a general relationship to a personal one.

Politics: According to the first-year mathematics syllabus of Procity University, students are expected to formulate and solve quadratic equations; in the context of the syllabus this comprises social goods. These goods were worth having in solving the algebraic task. S8 made assumptions using arbitrary values and then formulated a mathematical expression. In making the assumptions, he used formal mathematical language as used in mathematics Discourse. He then used the arbitrary values to formulate the mathematical expressions. Therefore S8 can be recognised as a student who distributed social goods across the task using formal mathematical language within mathematics Discourse.

Connections: S8 is connecting his arguments with conceptual mathematics discourse (see Sfard, Nesher, Sreefland, Cobb & Mason, 1998). This is evident in the way he connects unknown values of rows and chairs with some arbitrary values within the task, enabling him to formulate the required mathematical expression(s). As Extract 8.2 shows, he connected the word “algebra” with unknowns. While this connection is not obvious in mathematics, it formed part of his first thoughts about the task. S8 described the assignment of arbitrary values to the unknowns and explicitly justified why he did so. By justifying, he connected his conversation to conceptual mathematics discourse. Furthermore, pointing connected his verbal explanation with his written work. This connection was necessary because he first worked out the task on his own before he explained his interpretation. S8 is thus recognised as a student who made connections within the task, with conceptual mathematics discourse and connected his verbal explanation with his written work.

Sign systems and knowledge: Throughout Extract 8.1, S8 used formal mathematics language (in English) as noted in the discussions above. For example, in assigning arbitrary values to the unknown number of rows and chairs when he said "So you give the number of rows an arbitrary letter like ***a***". While this language is acceptable in mathematics discourse, it did not involve words commonly used in making mathematical assumptions, but it is clear that he was involved in making an assumption. Therefore S8 privileged using formal mathematics language in English in his verbal explanation.

With the awareness that S8 used Kiswahili and English when working on mathematics when on his own, with peers and lecturers and the fact that he also used Kikuyu at home, I inquired about his use of other languages in this particular task during the reflective interview. He responded as follows:

Extract 8.4

S8: Kiswahili only … even I found the answer using Kiswahili because now I was reading the question and interpreting it into Kiswahili and even these things I was writing I was saying wacha hii ikuwe hivi [Let this one be like this]{referring to scribbles on arbitrary values on the question paper} so in Kiswahili.

R: Why did Kiswahili come into play?

S8: Because I'm mostly acquainted to Kiswahili as a language; I'm best in Kiswahili than in English[31]. So it was the language that I was using to

[31] This comparison of performance in Kiswahili and English was not based on any academic records.

> interpret now this. So, even though it's written in English here, whatever was coming from my mind was in Kiswahili. I was just writing in English because it's like a requirement.

S8 said that he used "Kiswahili only" meaning that he did not switch to Kikuyu in the particular task. He read the question as it was and interpreted it in Kiswahili. By listening and observing him interpreting the task, I could not tell that the arbitrary values had been thought of in Kiswahili since these were all written in English on his worksheet. In using languages that way, he privileged Kiswahili, his home language, in interpreting the task.

S8's use of Kiswahili was based on the fact that he was more familiar with Kiswahili than with English. This resonates with research findings (see e.g. Parvanehnezh & Clarkson, 2008) that show that some bilingual students switch between LoLT and home language because they are more familiar with the home language than the LoLT. Furthermore, S8 said that he was more proficient in Kiswahili than in English. Being "better in Kiswahili" than in English probably meant that he was more fluent in Kiswahili since Kiswahili was his home language; he used it at home and with the larger community. This explains partly why S8 used Kiswahili more than Kikuyu. He commonly used both English and Kiswahili in his thought and with his peers and lecturers.

S8 wrote only in English because it was a university requirement. This positions English as a powerful language in S8's communication of the task. Given the powerful position of this language, he communicated in English whereas he could have done the task in the familiar language of Kiswahili. The perspective of English holding more power than Kiswahili in S8's case is similar to the view that English is the language through which one may gain access to social goods such as employment and language of examination (see Setati, 2008). Since initially S8 had a choice of the language in which he preferred to be interviewed, in my view S8 restricted himself to using English in his communication with me because of the power that English is regarded as having.

In essence, S8 translated the whole task from English to Kiswahili, solved it and then wrote it down in English. The two languages had different functions; Kiswahili was a language for internal communication that he used for thinking and interpreting the task, while English was for external communication, used in writing and verbal communication with the researcher. He switched to Kiswahili for the purpose of translating the task because of his familiarity with the language. Therefore, code switching supported S8's participation in competent mathematics Discourses.

After interpreting the task and assigning arbitrary values to the rows [***a***, and (***a***+5)] and chairs [(***n***, and (***n***-6)], he formed simultaneous equations.

b. In solution process

S8 labeled the simultaneous equations *(i)* and *(ii)* as below.

$$\left(\frac{600}{a}\right) = n ... (i)$$

$$\left(\frac{600}{(a+5}\right) = (n-6) ... (ii)$$

Using equation *(i)* above, S8 expressed ***a*** in terms of ***n*** to get ***a*** **=** 600/***n*****.** He then substituted for ***a*** in equation *(ii)*. He proceeded to solve as follows:

Extract 8.5:

S8: Now ***a*** **=** 600/***n***, I substitute the value of ***a*** in equation *(ii)*, I substitute it with 600/***n*** now in equation *(ii)* because here in equation *(ii)* we have two unknowns and it's not possible to do {workout} a sum with two unknowns. So equation $\frac{600}{\left(\frac{600}{n}\right)+5} = n-6 ...$ *(ii)* {which he simplifies to obtain $600 = (n-6)(\frac{600}{n}+5)$ } …will have one unknown, which will be ***n*****.** Now here ***n*** what you do, you multiply both sides by this denominator {***n***} so that you can eliminate it now from being a denominator …

In what follows, I analyse S8's language practices from his utterances in Extract 8.5 above.

Table 8.2 Analysis of S8's utterances in solution process

Discourse situation	**Key words/phrase/actions**	**Indicators of patterns of cues and clues in the response**
Significance	I substitute the value of ***a***/ I substitute it with 600/***n***/ now in equation *(ii)* because here in equation *(ii)* we have two unknowns and it's not possible to do a sum with two unknowns/ you multiply both sides by this denominator {***n***} so that you can eliminate it now from being a denominator	He used words and constructed sentences that made the process of substitution significant. The words and sentences are part of mathematics Discourse.
Activity	I substitute it with 600/***n*** now in equation *(ii)* because here in equation *(ii)* we have two unknowns and it's not possible to do a sum with two unknowns	He is making substitutions and justifying the process.
Identity	I substitute the value of ***a***/ I substitute it with 600/***n***/ we have two unknowns/ what you do you multiply both sides/ so that you can eliminate	His identity moves from one of an individual mathematician to one associated with the mathematics community.
Relationship	I substitute the value of ***a***/ I substitute it with 600/***n***/ we have two unknowns/ what you do you multiply both sides/ so that you can eliminate	The relationship is transformed from that of an individual mathematician to one involving other mathematicians, which is in keeping with how language is used in mathematics Discourse.
Connections	I substitute the value of ***a*** in equation *(ii)*/ I substitute it with 600/***n*** now in equation *(ii)/* because here in equation *(ii)* we have two unknowns /and it's not possible to do a sum with two unknowns/ you multiply both sides by this denominator {***n***} so that you can eliminate it now from being a denominator	By substituting one for the other he made connections within the task. Furthermore, he made connections with mathematics register, formal mathematical language and conceptual mathematics discourse.
Sign systems & Knowledge	I substitute the value of ***a*** in equation *(ii)*/ I substitute it with 600/***n*** now in equation *(ii)*/ because here in equation *(ii)* we have two unknowns /and it's not possible to do a sum with two unknowns/ you multiply both sides by this denominator {***n***} so that you can eliminate it now from being a denominator	He used a formal mathematics language and drew on equations to solve the task.

Significance: S8 made the process of substitution significant using words and constructing sentences that explicitly explained this process. He used terms such as substitute, denominator and eliminate, which were in keeping with his solution process and are part of the mathematics register (see Halliday, 1974 in UNESCO, 1974; Pimm, 1987). Furthermore, he explained and justified the substitution processes that are practices with which mathematicians engage (see Moschkovich, 2002). In fact, he used formal mathematics language throughout the extract.

Activity: S8 substituted the value of ***a*** as formulated from equation *(i)* into equation *(ii).* He justified why he did so; a single equation in two unknowns cannot be solved. This meant he could not solve either equation *(i)* or *(ii)* on their own; rather, ***a*** needed to be formulated from *(i)* and substituted for in *(ii)* so that the resulting equation had one unknown value. This activity is consistent with the process of solving simultaneous equations.

Identity: While S8 had worked on the whole question by himself and was explaining from his written work, he identified with his personal view and that of the mathematics community. S8's use of personal and impersonal pronouns corresponds with how mathematicians use language; as explained by Pimm (1987) and Rowland (1999), mathematics is not entirely impersonal. He personalised the process of substituting ***a*** using the pronoun "I". In doing so, he marked a personal action in the substitution process. He used the impersonal pronoun "we" in explaining the unknowns and justifying the need for substitution, and he used "you" in an attempt to simplify the equation with one unknown value ***n***. "We" and "you" here indicate that S8 worked as other mathematicians. Furthermore, his approach and the words he used in the solution process were typical of how things are done in mathematics. S8 is thus recognised as a student who, while referring to what he had actually worked on on his own, moved from the position of individual mathematician to one where he referred to himself as one of the community of mathematicians with whom he shared the knowledge of solving the task.

Relationship: The way in which S8 moved from "I" to "we" and to "you" and the words and sentence construction he used transformed his relationship from a personal relationship in explaining the process of substitution, to a general relationship between him and other mathematicians in justifying the substitution process and simplifying the quadratic equation. In general, his words and sentences show that he engaged with valued mathematics Discourse practices.

Connections: By substituting, S8 connected the two equations in his solution process. In addition, he used formal mathematics language, rich in terms such as substitute, eliminate, and denominator that are found in the mathematics register, thus making connections with formal mathematics language. His justification for his substitution of the value shows that he connected his explanation to conceptual mathematics discourse. S8 is recognised as a student who used language to connect the equations he formulated within the task, and valued mathematics Discourse practices.

Sign systems and knowledge: Throughout Extract 8.5, S8 used formal mathematics language and drew on equations to solve the task. After substituting the value of $\boldsymbol{a}$ in equation *(ii)*, S8 formed a quadratic equation in $\boldsymbol{n}$**,** which he needed to solve for. He chose to use the formula method as in Extract 8.6 below, drawn from a later section of his solution process.

Extract 8.6

S8: … and you get $30\boldsymbol{n} = 5\boldsymbol{n}^2-3600$ now this one is a quadratic equation {which he rearranged to get $5\boldsymbol{n}^2-30\boldsymbol{n}-3600=0$} so you solve it with either way of the quadratic equation. So I've chosen the formula because it's the most convenient and it will be easier and it's fast.

R: Which are the other methods that you can apply?

S8: You can use completing the square method you can use the factorisation method.

The utterances above show that while S8 used the formula method, he was aware of different methods, such as completing the square or factorisation, to solve the quadratic equation. He argued that the formula method was most convenient, easier to use and that he would approach the solution faster using this method. By choosing the formula method, S8 showed his preference of the method. Thus S8 can be recognised as a student who used mathematical English throughout his verbal and written explanation in the solution process and as one who privileged the formula method to solve the quadratic equation.

As indicated in Extract 8.4 above (in the analysis of S8's interpretation of the task), S8 used Kiswahili in thinking throughout the solution process. The written solution process involved mainly numbers and variables. These are written in the same way in both Kiswahili and English. Thus it is not possible to determine what was written in Kiswahili and what in English. For this reason, S8 is recognised as a student who used Kiswahili internally in the solution processes.

Discussion of S8's interpretation and solution process

S8 made formal mathematics language significant. He used it in describing, formulating, making assumptions, substituting and justifying both the interpretation and the solution process. At times he positioned himself as working from a personal point of view and at others as working with other mathematicians. He personalised his identity mainly when he referred to his earlier written work. He used language to make connections within the task and with the mathematics register, formal mathematics language and mathematics Discourse practices. He also connected his verbal explanation with his written work. He privileged the quadratic formula to solve the quadratic equations. In all his verbal and written explanations, he used a formal mathematics language in English while he thought in Kiswahili. He used Kiswahili because he was more familiar with it than with English.

Therefore S8's utterances in interpreting and solving the task contained cues and clues for mental code switching, formal mathematics language, and conceptual mathematics discourse, and general and personal relationships with other mathematicians and mathematical Discourse practices in general.

8.2.1.2 S8 negotiating the situated meaning of key word "hall"

S8 situated the meaning of a hall from the perspective of an auditorium or a theatre. In an informal session and away from the interview sessions, he explained his high school experience of theatres, as being elevated from front to back. Like S2 (in section 7.3.1.2), S8 had experience with theatres as a student of English and Kiswahili literature in high school. Thus he operated with the Discourse model of a hall as an auditorium or a theatre.

8.2.1.3 Emerging Discourses

From the discussion on the cues and clues in S8's language practices in interpreting and solving the task and the situated meaning and accompanying Discourse model, it is clear that S8 "pulled off" the Discourse of a student who combined and integrated verbal words with gestures, formal mathematics language, and conceptual mathematics discourse, mathematics register, and mathematics Discourse practices. He did so by switching from English to Kiswahili to translate the whole task in his thinking, his interpretation and the working out of the task. He assumed both the general and personal perspectives of a mathematician whose view of the hall in question was of an auditorium or a theatre.

In the next section, I discuss how S6, S10 and S15 used languages as they interpreted and solved the task. Part of the language practices of these students that involved identifying and explaining cues and clues in the seven Discourse situations are similar to the language practices of S8. However, the practice of code switching was different and how and why other languages were used is key to this study. Hence, the section focuses on the language practice of code switching between English and students' home languages. The analysis supported the findings on S8's utterances and raised other pertinent issues of interpretation and solution processes in the task when code switching occurred.

8.2.2 Language practices of S6, S10 and S15 in the interpretation and solution process

S6 translated the task into Kiswahili. He explained what the task required of him in both verbal and written forms in English only. This 21-year-old Mechatronics Engineering student explained that although Kikuyu was his first language, the fact that he came from a linguistically heterogonous community in the Rift Valley province[32] like S8, Kiswahili was the common language of communication and actually his home language. He had a better understanding of Kiswahili than of English and this was the reason for his mental translation of the whole task into Kiswahili in order to understand it better.

S10 translated the task into Kikamba because it was the more familiar language. He was a Civil Engineering student aged 19 years. His home language was Kikamba. He rarely used either Kiswahili or English at home. All three languages were relevant to him when engaging with mathematics in that he used all of them when thinking about a task and when discussing it with his peers. He used Kiswahili and English with his lecturers.

In working on the task, S10 used English throughout his written and spoken explanation of his interpretation. He initially thought the task was about permutations, but later

[32] Rift Valley is a province of Kenya that is occupied by people from diverse ethnic and language backgrounds.

changed his mind and solved the task correctly. In his reflections, he revealed that he used Kikamba to interpret the whole task.

Extract 8.7

R: ... Did other languages come anywhere in between when you were responding to the question?

S10: Yeah, yeah, yeah. First, after seeing the question, in all my studies, I try to interpret in Kikamba, which I'm more conversant with. I read in English then I interpret it in Kikamba, which I can understand more than English.

R: Are there particular parts or it is the whole question that …. {S10 interjected}

S10**:** The whole question.

R: How do you put it in Kikamba?

S10: I do it in Kikamba then I transfer to the paper in English.

R: Is it {translation} something that you can write?

S10: No, no, no.

Yeah, I'm more conversant with Kikamba more than any other language.

This extract reveals that S10 not only translated the present task but that he did this with all tasks. His reason was that he was more familiar with Kikamba than with English. He interpreted the task to Kikamba in his mind but neither verbalised it nor wrote it down in this language. It was interesting that when requested to write the interpretation in Kikamba, S10 gave an emphatic "no", despite arguing that he was more fluent in this language than in any other. While this explanation may seem to contradict his use of Kikamba, in a way it demonstrates that conversational proficiency in a language is not commensurate with written proficiency (see Gerber et al., 2005). He used English to communicate the task expectation, interpretation and solution process to the researcher. Kikamba his home language was significant for understanding and interpreting the task while English served to communicate with the researcher.

Similarly, S15 read the task in English then interpreted it internally in his home language, Kikuyu, for better understanding. He wrote out the solution process in

English, a practice that he followed in other tasks. Like S10, S15 could not write the translation in Kikuyu although he could speak the language.

Discussion

The language practices of the trilingual students S8, S6, S10 and S15 above show that they translated the whole task into their home languages mentally when interpreting the task because they were more familiar with the languages. They then reported in English. The fact that they used their respective home languages for mental translation supports Hoffmann's finding that some trilingual students use the LoLT for external communication while their others languages are used for internal communication (2001). Furthermore, these students translated their tasks in ways similar to those of English-French bilingual students who translated the French text mentally into English (see Kern, 1994). Their translations were associated with the common use of these languages as languages of communication within their home environments (S8, S6, S10, and S15) and/or in mathematics group discussions (S8, S6 and S10). Similar reasons were given by English-Vietnamese bilingual students in Australia when they switched between their two languages (see Clarkson 2006).

Setati (1998) observes that translation may pose challenges when everything has to be translated from one language to another. Citing English and Setswana, Setati observes that some of the mathematics terms are either not available at all in Setswana, or not readily available. The students in my study translated the whole task and did not report any challenges in translating the task. The fact that the task did not contain any technical terms could be the reason they did not report difficulties in translating from English to their home language and vice versa.

In the next section I discuss the language practices of S3 and S4, who switched languages in order to translate some parts of the task.

8.2.3 Analysis of S3's utterances in the interpretation and solution process

S3 was aged 19 years at the time of data collection. His home language was Luluhya. At home, he commonly communicated with his family in Luluhya, using English very seldom. In the questionnaire, he indicated that he communicated internally and with his peers in English more than in Kiswahili, while he used both English and Kiswahili with his lecturers. S3 was pursuing a degree in Geomatic Engineering and Geospatial Information Systems.

8.2.3.1 Identifying and explaining cues and clues

a. In the interpretation

S3 explained and wrote his interpretation simultaneously. In responding to what the question required of him, he explained:

Extract 8.8

S3: …/so the total number of chairs {writing} total number of chairs is 600 / then each row has the same number of chairs. If it is 20, 20, 20….per row is the number. {Reading from the question he continues}, so you just let the original number, original number of rows before the increase of rows be a value let's say ***x***. So after the increase the new number of rows is now (***x*** + 5), yes after the increase. But the number of chairs per row is decreased by, by six. So if there are ***x*** rows initially and the chairs the total number of chairs are 600 it means that the number of chairs per row in this will be 600/***x*.**

Table 8.3 Analysis of S3's utterances in the interpretation

Discourse situation	**Keywords/phrases/ actions**	**Indicators of patterns of cues and clues in the response**
Activity	If it is 20 {chairs}, 20, 20… per row is the number/ so you just let the original number, original number of rows before the increase of rows be a value let's say ***x***.	He uses a specific assumption about the number of chairs to arrive at a general assumption regarding the number of chairs.
Identity	so you just let/ let the original number /let's say ***x***.	He uses formal mathematics language as evidenced in the words "you let" and "let's" in making an assumption about the number of chairs.
Relationship	so you just let/ be a value let's say ***x***.	He used language in a way that is related to other mathematicians, creating a sense of generality.
Connections	If it is 20 {chairs}, 20, 20….per row is the number/so you just let the, original number of rows before the increase of rows be a value let's say ***x***/ So if there are ***x*** rows initially … it means that the number of chairs per row in this will be 600/***x*.**	He connects a specific assumption about the number of chairs to a general assumption regarding the number of rows ***(x)***. ***x*** is then connected directly to the number of chairs.
Sign systems and knowledge	…so you just let the, original number of rows … be a value let's say ***x***/ So if there are ***x*** rows initially … it means that the number of chairs per row in this will be 600/***x*.**	He uses formal mathematics language in English.

Activity: S3 makes a specific assumption about the number of chairs, that is, 20 chairs per row, which seems to lead to a general assumption about the number of chairs. The reason he first made a specific assumption before arriving at the general assumption is not obvious. It could be explained by his association of task context to a real life situation, as he explained during the reflective interview:

Extract 8.9

S3: First of all, when I read the question I looked at it and I tried to relate it to real life situation. When I /I read it further, I imagined myself arranging that… {Inaudible} maybe somebody has been appointed to arrange chairs in a certain hall. I was imagining if it were me, what could I do?
R: A real life situation …?
S3: It's like there is a meeting in a certain hall, and maybe the guests have been invited and everybody. So the chairs are supposed to be arranged maybe I'm there and I can be consulted/ to arrange those chairs. So I was imagining, I'm the one to be appointed to arrange those chairs what could I do?
R: Did that {real life situation} influence how you solved the problem?
S3: Yes in that, I was now seeing things like physically not like on the paper, because when I was focusing, the chairs as objects. That really motivated me, helped me a lot in solving that question.'

S3 explained his view of the real life situation as one in which guests had been invited to a meeting in a hall and he was required to arrange the chairs for them. The chairs were physical objects that assisted him in solving the task. While this activity was not visible when he was interpreting the task, it was important in understanding how S3 arrived at his assumptions. S3 is recognised as making assumptions based on a real life setting, a practice that is common in mathematics Discourse.

Identity: He refers to "you", "let" and "let's" in making an assumption about the number of chairs. "Let" is commonly used in formal mathematics language when making assumptions in the mathematics Discourse community and is a defining characteristic of mathematics register (see Halliday, 1974 in UNESCO 1974). Using the three referents, S3 positioned himself as working with and like other mathematicians who share the knowledge of making assumptions. In so doing, he assumed the general identity of one of these mathematicians.

Relationship: Following the general identity of belonging to the mathematics community, S3 created a general relationship with the community.

Connections: S3 makes connection within the task and with formal mathematics language. This is evident in that he initially makes a specific assumption about the number of chairs and then connects this to a general assumption about the number of rows, and finally the number of chairs. He uses formal mathematics language in his interpretation.

Sign systems and knowledge: Throughout the task, S3 used English; however, I wondered whether he used his home language and/or Kiswahili. In the questionnaire he had indicated that he engaged in mathematics in English and Kiswahili. In order to find out whether this also applied to the given task, I enquired how he had used other languages. S3 laughed before responding:

Extract 8.10

S3: {Laughs} in interpreting that question, yeah to some extent. For deeper understanding of the question, when I read it I tried to interpret it in my language which is Luhya[33]. I tried to translate the words written there in Luhya using my brain.

R: Are there specific words that you may have used in Luhya?

S3: Yes / like chairs is "izidindeve", "Izidindeve" are arranged in rows meaning chairs arranged in rows, arrange is "kubang'a". When I had these two words, I now know that, I had the deeper meaning of this question, because I understand this language better, it's my original language, the language that I learnt.

S3's laughter could explain the rarity with which questions on other languages are asked, especially at an advanced level of learning such as university. He may actually have wondered why I was concerned with other languages when mathematics is taught exclusively in English. S3 explained that he translated words like chairs and arrangement mentally. It was necessary for him to understand the words chairs as "izidindeve" and arrangement as "kubang'a" so that he could form a deeper

[33] Luhya is also referred to as Luluhya

understanding of what the task was all about. He translated these words into Luluhya because he understood that language better; as he put it, Luluhya was his original language, the language that he learnt first. This statement suggests that he relates closely with Luluhya and understands it better than English or Kiswahili. It was the more familiar language and hence was most relevant when interpreting the task. By translating the words he emphasised their meaning. However, the words were neither verbalised nor written while he was engaging with the task. While he understood Luluhya better than other languages, I wondered why he preferred to be interviewed in English. In his explanation, English was positioned as the official language and ought to be used in engagements such as interviews.

Extract8.11

R: Much as you understand the {Luluhya} language you preferred to be interviewed in English.
S3: {Laughs}. The language I thought that the English is the most official to be used in interviews.
R: Otherwise,
S3: If they could allow {laughs} for any other local language then I could choose on this {Luluhya}.

In the utterances in Extract 8.11, S3 reveals that he would have preferred to be interviewed in Luluhya if it was allowed. When he was given the opportunity to choose his preferred language for the interview, S3 chose English. This shows that he may have avoided using his home language because English was the official language in such communication and in such settings, particularly at university level. His choice of English shows the tacit power that the English held over S3's language practice. Furthermore, saying that "if they could allow {laughs} for any other local language then I could choose on this {Luluhya}" reveals that the permission given by the researcher in the context of data collection was not enough encouragement for him to use his home language. Therefore S3 kept to English in his verbal communication and switched to his home language when thinking as a result of the context in which he found himself at the time of the interview.

After explaining the initial conditions in the process of interpretation, S3 went on to work and explain the solution process.

b. In the solution process

S3 started with an explanation and expression of the changes after rearrangement as explained in the extract below;

Extract 8.12

S3: …So after the increase number of chairs per row is going to be 600/(***x***+5) / after these changes have been made, the number of chairs per row is decreased by five.

R: By?

S3**:** By six {corrected to six}. So therefore it means that, this one {600/***x***+5} is more than this one this value {600/***x***} by six {referring to (600/***x***+5) – (600/***x***) =6}…so we form an equation here…

R: Which value did you say is bigger than the other one? … Just start again: which is greater than the other one between these two? {(600/***x*** and 600/(***x***+5)}.

S3: Ok this value {600/***x***} is greater, is greater than this value {600/***x***+5}, so we take this minus (600/***x***) - (600/***x***+5) not the other way round {making the correction}. We have (600/***x***) - (600/***x***+5) = 6. Now we multiply by the LCM which is ***x*** into (***x***+5) {written as ***x***(***x***+5)}…

The table below reflects the cues and clues arising from his utterances as he solved the task.

Table 8.4 Analysis of S3's utterances in the solution process

Building task	**Key words/phrases**	**Indicators of patterns of cues and clues in the response**
Activity	this one {600/***x***+5} is more than this one this value {600/***x***} by six/ this value {600/***x***} is greater, is greater than this value {600/***x***+5}, so we take this minus (600/***x***) - (600/***x***+5) not the other way round	He is making a comparison of values and also making corrections to the differences.
Identity	so we form an/ we take this minus/ We have (600/***x***) - (600/***x***+5) = 6/ we multiply by	He identifies himself with other mathematicians.
Relationship	so we form an/ we take this minus/ We have (600/***x***) - (600/***x***+5) = 6/ we multiply by	He is relating with the mathematics community as he explains the procedures.
Connections	after the increase number of chairs per row is going to be 600/(***x***+5) /this one {600/***x***+5} is more than this one this value {600/***x*** } by six/ this value {600/***x***} is greater, is greater than this value {600/***x***+5}, so we take this minus (600/***x***) - (600/***x***+5) not the other way round	He is making connections within the task and making comparisons between the algebraic expressions. He used one variable to form the required equation.
Politics	…after the increase number of chairs per row is going to be 600/(***x***+5) /this one {600/***x***+5} is more than this one this value {600/***x*** } by six/ this value {600/***x***} is greater, is greater than this value {600/***x***+5}, so we take this minus (600/***x***) - (600/***x***+5) not the other way round	He is involved in making simple expressions and quadratic equations.
Sign system and knowledge	…number of chairs per row is going to be 600/(***x***+5)/ this one {600/***x***+5} is more than this one this value {600/***x***} by six/ We have (600/***x***) - (600/***x***+5) = 6. Now we multiply by the LCM which is ***x*** into (***x***+5)	He valued forming two equations in a single variable to solve for the rows and chairs. He used English throughout the solution process.

Activity: S3 was involved in the activity of making comparisons; he expressed the number of chairs in terms of rows and then compared them so as to form a quadratic equation. At first he incorrectly stated the expression of the difference; he later corrected it.

Identity: In carrying out the operations, S3 used the pronoun "we". Furthermore, he used the language and approach to the operation that is used in the mathematics community; hence he identified himself with other mathematicians.

Relationship: In his reference to "we", S3 related to the mathematics community as a participant.

Connections: S3 made connections with the mathematics register (Halliday, 1974 in UNESCO, 1974; Pimm, 1987; Rowland, 1999) and formal mathematics language (Setati and Adler, 2000). This was evident in the way he connected different parts of the task before and after the rearrangement. Furthermore, S3 used one variable, ***x***, to connect the number of rows to the number of chairs and related the different values by subtraction. He then derived a quadratic equation. He used formal mathematics language throughout the explanation and solution process. His mode of expression in the different parts was consistent with the way mathematics register and formal mathematics language is used.

Politics: Deriving equations and simplifying them is a social good attached to the first-year algebra module at Procity University. From his assumed values, S3 formed simple equations. He then connected the equations to form a quadratic equation, which he then simplified by eliminating the denominator.

Sign system and knowledge: S3 used a single variable to relate the number of chairs to the number of rows. He privileged the one variable method to arrive at the quadratic equation. He then solved the equation to arrive at the required number of chairs and rows. He used English throughout the explanation of his solution process. There was no indication in this process that he had switched to either Luluhya or Kiswahili.

Discussion

In summarising the language practices of S3 in interpreting and solving the task, it was observed that he made the required assumptions based on a real life situation, as mathematicians do. He used a single variable to form simple equations, expressing the difference between them and arriving at the required quadratic equation. He used plural pronouns which suggested that he identified with and worked in collaboration with members of the mathematics community.

S3 switched to Luluhya in his thinking in order to emphasise the meaning of the words "chairs" and "arrangement", arguing that when he translated them to the more familiar language, he formed a better understanding of the task. Emphasising the two words resonates with the observations of Merritt et al., (1992) where a teacher emphasised some words by translating them to a language that was more familiar to the students. In contrast, S3 was restricted from switching to his home language in his verbal communication by the interview context. He believed that, in such a context, English was the most appropriate and the official language. This is consistent with findings that bilingual students kept to the LoLT (Planas & Civil, 2008; Planas & Setati, 2009). He may not have felt entitled to use his home language, Luluhya. In fact, like the bilinguals in the study by Planas and Setati (2009), he probably did not view his language as valued in such a context. Furthermore, the fact that the researcher addressed the students in English from the beginning of the exercise may have prevented S3 from code switching. This avoidance of code switching left me wondering how students could be convinced that they could switch between different languages as they communicated verbally in a given context. After switching to translate the two words into Luluhya in interpreting the task, he did not indicate that he switched between codes in the solution process at any other time.

In his explanation, S3 makes connections with the mathematics register and formal mathematics language, which suggests that he identified himself, and related, with the mathematics Discourse community.

S3's utterances contained cues and clues to mathematics register, formal mathematics language, generality, code switching during thinking, and mathematics Discourse practices.

8.2.3.2 Situated meaning of words "chair" and "arrangement"

According to S3, in his understanding of the task he focused on grasping the meaning of the words "chairs" and "arrangement" (see Extract 8.10). He situated the meaning of these words in a real life situation of a hall. He imagined himself arranging the chairs in a hall where a meeting was scheduled; this helped him to view the chairs in the task as physical objects (see Extract 8.9). It seems that it was in such an environment that he could talk about chairs as "izidindeve" and about arranging as "kubang'a". Thus he situated the meanings of "chairs" and "arrangement" relative to his socio-culturally defined experiences of how he could arrange chairs in such a familiar setting. He applied the situated meanings to a Discourse model of a hall in his familiar environment and the socio-cultural practices involved in such an environment.

8.2.3.3 Emerging Discourses

From the preceding discussion on how S3 used language, he was recognised as having "pulled off" a Discourse of combining and integrating English and his home language in interpreting the task. He mentally translated some key words in the task into his home language to emphasise meaning for the sake of gaining deeper understanding. Further he combined and integrated formal mathematics language, mathematics register and mathematics Discourse practices and he identified himself with the mathematics community. He also operated in the Discourse of a student who viewed the use of other languages in his communication with the researcher as restricted.

Having analysed S3's language practices in detail, in the next section I explain how S4 used languages when he interpreted the task. The description focuses only on code switching between English and his home language, Dholuo. The analysis supported the findings of the analysis of S3's utterances and raised two pertinent issues related to the use of English and the home language in the interpretation of the task.

8.2.4 Language practices of S4

S4 spoke Dholuo at home more often than both English and Kiswahili; Dholuo was his home language. When doing mathematics alone and with peers he worked in English and Kiswahili, but he used English with his lecturers. He was enrolled for a degree in Geomatic Engineering and Geospatial Information Systems.

S4 switched between English and Dholuo, in a similar manner to S3's switching between English and Luluhya. For instance, in responding to what the task required of him, and in fact throughout the task, his verbal and written explanations were in English. I asked him during the reflective interview whether and, if so, when he used Kiswahili and/or Dholuo in solving the task. He answered that he translated the task at the interpretation stage; in particular, he had translated the third sentence into Dholuo because he found it difficult to interpret the English. His translation was "ka imedo rows a abich to igolo kombe auchiel e kila row. Ibro dong gi rows odi gi kombe adi e kila row". The interpretation helped him to formulate the quadratic equation correctly. In solving it using the quadratic formula, he missed one sign and therefore ended up with a negative number under the root sign. He was however not able to solve it.

In his words, Dholuo was the language that he was most familiar with and translating the sentence made it easier for him to understand the rearrangement and the task in general. Therefore, S4 privileged translating the part of the task that he found particularly difficult into his home language in order to understand it better.

I observed that when I asked S4 to tell me more about his translation, in his response he first asked whether he could speak in Dholuo. I responded in the affirmative. S4's request to use Dholuo indicated that it was rare for students to use languages other than English at this level in Kenya, especially in communication outside their social circle. His request to verbalise and write in Dholuo resonates with S3's response when he said that if he had been allowed to he would have used Luluhya in the interviews.

Discussion

Students may switch between languages in order to express words or phrases in the more familiar language. S3 and S4 switched to Luluhya and Dholuo respectively because these languages were more familiar to them than the LoLT. At the same time they needed to gain a better understanding of the task. While S4 faced challenges in understanding the third sentence and thus translated it into his home language, S3 needed further understanding beyond what he had captured in English.

8.3 Findings on language practices involving the use of English and home languages

The language practices of the two trilingual students, S8 and S3, show that they used languages to make assumptions, formulate mathematics expressions and justify their workings. They constructed sentences that were rich in the words and modes of argument used in the mathematics register and in formal mathematics Discourse. Furthermore, they identified with and related to the mathematics Discourse community. One student (S8) used gestures to support his arguments. These practices were typical of the language practices of the other four students who were discussed in sections 8.2.2 and 8.2.4 above.

Of the six students, four switched mentally to translate the whole task while the remaining two switched to translate parts of the task. They all switched to their home language because they were more familiar with the languages than they were with English, the LoLT. For the four who translated the whole task, translation was a normal practice that they engaged with in other tasks, while for the other two their switching and translation was limited to the interpretation of this task. One student (S3) translated particular words to form a better understanding of the task.

What these findings show is that students' home languages, which were Kiswahili and other indigenous languages Kikamba, Luluhya and Kikuyu, were resources for these trilingual undergraduate students when engaging with mathematics. These indigenous languages are not, however, taught or used at university level in Kenya (Gachathi Report of 1976, in Mbaabu, 1996).

In general, it was found that trilingual students switched between English and their home languages similar to how bilinguals use their two languages and positioned themselves in mathematics Discourse community.

8.4 Conclusion

In this chapter, I discussed the analysis of the language practices of six trilingual undergraduate students who switched between two languages when engaging with a mathematics task. The analysis included how the students used two languages in interpreting and solving the mathematics task.

The findings revealed that some language practices were more pronounced in the interpretation than in the solution process. For instance, code switching was more prevalent in the interpretation process. This might suggest that once the students had formed an understanding of the task, this understanding enabled them to navigate the solution process in English without relying on their home languages. When using either of their other two languages, the students' language practices were similar to those of bilingual students.

In the next chapter I discuss how some students used three languages to engage with the mathematics task.

CHAPTER 9

LANGUAGE PRACTICES INVOLVING THREE LANGUAGES

9.1 Introduction

In this chapter I discuss the analysis of the language practices of two trilingual undergraduate students who used their three languages as they engaged with the mathematics task. These students switched between English, their home language and Kiswahili either explicitly and/or implicitly. Findings showed that the home languages were the dominant languages that the students used to make sense of the task.

The students who engaged in three languages in the task were S14 and S13[34]. Their home languages were Dholuo and Kikuyu respectively; these were also their first languages.

9.2 Analysis of S14's utterances in the interpretation and solution process

S14 was 21 years old. At home he commonly used Dholuo with his family; English and Kiswahili were rare languages of communication. When doing mathematics on his own and with his peers, he commonly switched between English and Kiswahili, and he communicated with his lecturers in English. In his KCSE he scored Grade A in mathematics and Grade B in English. He was enrolled for a degree in Civil Engineering.

9.2.1 Identifying and explaining cues and clues

a. In the interpretation

S14 first read the task on his own and then explained what it required him to do.

[34]Other than S14 and S13, who used their three languages in interpreting and solving the task, S11 indicated that he used all the three languages but he did not use them in solving the question in this study. He used English only, as discussed in Chapter 7.

Extract 9.1

S14: The question requires me to / employ the idea of quadratic {methods} to solve / the number of rows and the number of chairs.

R: How do you know that it requires you to use quadratic methods?

S14: I come to realise that you can at this level, / we are told that {reads question aloud} the number of chairs is increased by five but the number of chairs per row is decreased by six. The first scenario, we are going to let the number of rows to be ***r*** and then the number of chairs I may say to be ***c*** so in the second scenario ***r*** is now increased by five you take ***(r****+5)* and then number of chairs now when you subtract six since it has been decreased. So somehow naona kama inaleta [I see like it will result in] quadratic equation.

The cues and clues in the interpretation of the task are highlighted in Table 9.1, followed by a discussion of these.

Table 9.1: Analysis of S14's utterances in the interpretation

Discourse situation	**Key word/phrase/actions**	**Indicators of patterns of cues and clues in the response**
Significance	The question requires me to / employ the idea of quadratic {method} to solve… So somehow naona kama inaleta [I see like it will result in] quadratic equation	He makes the use of quadratic method and equations significant.
Activity	I come to realise that … we are told that…/The first scenario … let the number of rows to be ***r*** and … chairs I may say to be ***c***. /So somehow naona kama inaleta [I see like it will result in] quadratic equation.	He gives a justification for using the quadratic method, making assumptions and tackling the solution process in two logical steps. He emphasises that the operation of the expressions would probably result in a quadratic equation.
Identity	The question requires me to / I come to realise/you can/we are told/ we are going to let/I may say/ you take (***r***+5) / when you subtract/ 'naona kama inaleta …' [I see like it will result in]	He identifies himself at once as an individual mathematician and as a member of the mathematics community. He uses words and approaches the task in ways that are used in the mathematics Discourse community.
Relationship	The question requires me to / I come to realise/you can/we are told/ we are going to let/I may say/ you take (***r***+5) / when you subtract/ 'naona kama inaleta…' [I see like it will result in]	His relationship with other mathematicians shifts from that of an individual engaged with operations to one of sharing information and working with other mathematicians. Kiswahili is used to emphasise his claim.
Connections	The question requires me to / employ the idea of quadratics (methods)/ I come to realise that … we are told that…/The first scenario we are going to let the number of rows to be ***r*** … in the second scenario ***r*** is now increased by five you take (***r***+5)…/So somehow 'naona kama inaleta' [I see like it will result in] quadratic equation.	He is connecting the task to a specific area of mathematics; quadratics, and justifies why he thought so. He is also connecting the assumed values to the known values, using two logical steps, and he emphasises that he needs to use quadratic methods to solve the task.
Sign system and knowledge	…employ the idea of quadratic to solve…/So somehow 'naona kama inaleta' [I see like it will result in] quadratic equation.	He makes the quadratic method relevant to solve the equation. Furthermore, Kiswahili is privileged in emphasising his earlier claim that the question requires the formation of a quadratic equation.

Significance: S14's first thoughts were that the task required the use of quadratic methods. From his utterances, it seems that the fact that he had to make assumptions and then make simple equations informed the need to use quadratic methods. Therefore S14 made solving the task using the quadratic methods significant.

Activity: S14 was involved in a range of activities that signified his engagement with conceptual mathematics discourse (Sfard et al., 1998) and mathematics Discourse practices (see Moschkovich, 2002). For instance, after indicating that the question required the use of quadratics, S14 went on to justify why he thought so. Using some assumed values for the chairs and rows, he set out two logical steps to enable him to form a quadratic equation. At the end of the explanation he emphasised that the solution process would result in a quadratic equation.

Thus S14 is recognised as a student who proposed what the task required and went ahead to justify it by making the necessary assumptions. Making assumptions, justification and logical coherence are practices that are valued in mathematics Discourse (Moschkovich, 2002).

Identity: S14 used the pronouns "me" and "I", later "we" and finally "I". His use of these pronouns is consistent with how they are used in mathematics (see Pimm, 1987; Rowland, 1999). The use of these pronouns shows that S14's identity shifted between that of an individual mathematician who made the proposition, to the general perspective of mathematicians with whom he shared knowledge of making assumptions on rows, and then back to that of an individual mathematician to emphasise his initial thoughts. He emphasised his thoughts in Kiswahili. He used words and approached the task in ways that are used in the mathematics Discourse community. This identified him as a student mathematician who suggested what should be done in the task, involving other mathematicians in the process of making sense of it, and finally reinforcing his suggestion on the kind of equation that he thought would result. His identity was not stable.

Relationship: With the change in the use of pronouns from individual mathematician to identifying with other mathematicians, S14's relationship with others was shown to be unstable. Furthermore, S14's switch to Kiswahili positioned him as assuming a shared understanding of the language with the researcher and hence a shared relationship.

Connections: S14 connected the task to a specific area of mathematics: quadratics. He justified why he thought the quadratic method was appropriate. By justifying, he participated in conceptual mathematics discourse. He connected the task to quadratics by assigning some arbitrary values to the unknowns in two logical steps. Eventually he emphasised that the operations would result in a quadratic equation. In his explanation, he used formal mathematics language to make an assumption and in using the assumed value. By making assumptions and logically taking steps to solve the task, S14 participated in competent mathematics Discourse (see Moschkovich, 2002). Therefore, S14 made connections with formal mathematics language and valued discursive practices in mathematics Discourse.

Sign system and knowledge: S14 made the quadratic method relevant as the method he would use in solving the task. He switched from English to Kiswahili to emphasise the claim that the task required the formation of a quadratic equation. The use of Kiswahili was not related to the mathematics, but was a way of emphasising his claim. In so doing, he made Kiswahili the relevant language for his emphasis. S14 was thus recognised as a student who privileged the use of quadratic methods in solving the task and using Kiswahili to make his claim. While the switch to Kiswahili was the only notable example of code switching practice in the interpretation, during the reflective interview S14 revealed that he used Kiswahili almost throughout the engagement with the task to read some numerals. Prior to the utterances in Extract 9.2, S14 explained the languages he had used in solving the task and then continued to explain how and why he used Kiswahili.

Extract 9.2

R: There was also the mention of Kiswahili, tell me how you used it in this question.

S14: Kiswahili I used it almost throughout.
R: Tell me how you used it.
S14: I used it when I was referring to the numbers here like 600, like 6, like 5.
R: Why do you use Kiswahili for the numerals?
S14: At times.
R: Why?
S14: That one I'm not able to explain.
R: Does it mean every other time you see numerals you read them in Kiswahili.
S14: I always tend to read them {in Kiswahili}.
R: So even when you are reading this {quadratic} formula here, that 4… {Referring to the constant value 4 in the quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ }.
S14: But not such cases only at times ndio natumia [it's what I use], and I actually think maybe because I'm living with people… {inaudible} so most of the time we speak Kiswahili.

S14 read some numbers in Kiswahili, such as the numbers of chairs, rows and people. These were numbers of countable items and not numbers in equations. He thought he did this because in the university residence he was living with people with whom he commonly communicated in Kiswahili[35]. This was not unexpected since his fellow students may have come from different language backgrounds, thus Kiswahili, the national language, would be the only common language for social communication. Given this language use, Kiswahili is positioned as the dominant language in the university residence in S14's situation. This dominant language was the language that he

[35] The issue of communicating in Kiswahili in the university residence was explained in an informal session after the interview.

used to read some numerical values because his living environment had socialised him to visualise similar figures in Kiswahili. It was as a result of habitual reference to such numbers in Kiswahili that he switched to Kiswahili to read similar numbers, even when they were presented in English in this particular task. The switch perhaps supported S14 in making sense of the task. Habitual reading of words in one language and not in the given language is not new in mathematics education. In a study by Parvanehnezh and Clarkson (2008), Persian-English bilinguals switched to read English words, for instance "girl" was read as "doktar" in Persian because of the habitual use of this word in Persian. Therefore S14 switched to Kiswahili to emphasise his claim and as a result of the habitual use of the language in his social communication at university.

So far it is clear that S14 switched between two languages, English and Kiswahili. In the solution process, he made two attempts. In his first attempt, he used English throughout but in the second attempt there were instances in which he switched to Dholuo while re-interpreting some part in the solution process, which is presented below.

After he had explained to me what he thought the task required him to do, I asked S14 to solve the task in writing while explaining what he was writing and why. In the first attempt he worked it out as follows:

Extract 9.3

S14: So let the number of rows be ***r***. {Continues reading the question}, each row, so when you increase the number of rows by five you will have (***r***+5) but the number of chairs per row is decreased by, by six. So if originally we had ***c*** chairs, so this scenario is going to be *(**c**-6)*. So find the original, so the number of chairs altogether is 600. Ok / you can say ***c*** {he goes ahead to calculate as he explains and gets a quadratic equation}…, so take ***c*** (***c***-6) =600.

R: You have multiplied the original number of chairs and the new chairs?

S14: Yes…to get c^2-6***c***-600 = 0. Then applying the quadratic formula, you can use the quadratic formula or the completing the square method ….

My question here was meant to alert him to the fact that he had made a mistake but he did not realise it; he eventually worked out the number of chairs to be 27. At this juncture, I indicated to him that we needed the original number of rows. This prompted him to reassess his solution process and he enquired whether he could rework it. While I responded in the affirmative, I asked him to explain what the information part of the task meant. He went on to explain as he wrote and arrived at the correct solution. It was in this second attempt, as he indicated during the reflective interview, that he switched to Dholuo to reinterpret the task and hence provide the analysis below.

b. In the solution process

When solving the task, S14 explained, wrote and justified the steps he took.

Extract 9.4

S14: … the total number of chairs in the hall is 600…these chairs now {are} arranged again in rows such that each row has the same number of chairs…

R: What does that mean?

S14: …from there we can get the number of chairs in each row. If we had r rows and the total number of chairs is 600, it means each row can accommodate $600/r$ chairs. If we increase the number of rows by five, then each row has $600/(r+5)$ chairs. So there is a relationship between $600/r$ chairs and $600/(r+5)$ chairs in that we are told that the number of chairs decrease by 6. So we have $600/r - 600/(r+5) = 6$ {he proceeds to simplify the equation up to $6r^2 + 30r – 3000 = 0$ then he says}…we want to form a quadratic equation, so we can divide through by six…ending up with $r^2 + 5r – 500 = 0$. So we can now identify $a = 1$, $b = 5$ and $c = -500$. So applying quadratic equation to solve for r {he proceeds to substitute the coefficients into the quadratic formula and to solve for r to get the value of $r = 20$ or $r = -25$ and proceeds} r was representing the number of rows, the number of rows cannot take a negative {value} so the realistic value of r is 20, so there were 20 rows.

The table below reflects how S14 used languages in his second and correct attempt at the solution process.

Table 9.2 Analysis of S14's utterances in the solution process

Discourse situation	**Keywords/phrases/ actions**	**Indicators of patterns of cues and clues in the response**
Activities	If we had ***r*** rows / So there is a relationship between 600/***r*** chairs and 600/(***r*** + 5) chairs in that we are told that the number of chairs decrease by six/ The number of rows cannot take a negative {value} so the realistic value of ***r*** is 20.	He is making an assumption, comparing and differentiating values and justifying the choice of his solution.
Identities	we can get/ If we had ***r/*** If we increase/ So we have/ we want to form	He positions himself as part of the mathematics community.
Relationship	we can get/ If we had ***r/*** If we increase/ So we have/ we want to form/	He creates and sustains a relationship with members of mathematics Discourse community.
Politics	So applying quadratic equation to solve for ***r***/ The number of rows cannot take a negative {value}/ so the realistic value of ***r*** is 20, so there were 20 rows.	S14 is identifying a method that could be used to solve the quadratic equation so formed and differentiating the answers obtained in order to state the appropriate answer.
Connections	If we had ***r*** rows ….it means/ If we increase … then…/ So there is a relationship between 600/ ***r*** chairs and 600/(***r*** + 5*)* chairs/ The number of rows cannot take a negative {value}/ so the realistic value of ***r*** is 20, so there were 20 rows.	He draws on the mathematics register, stating the assumptions and justifying the solution. He connects claims to valued practice in mathematics Discourse.
Sign systems and knowledge	we want to form a quadratic equation/ So applying quadratic equation to solve for ***r***	He uses the quadratic formula to solve the quadratic equation. S14 uses English throughout the extract.

Activity: S14 was involved in a range of activities that reflected his participation in mathematics Discourse practices, as described by Moschkovich (2002). First he made an assumption about the number of rows. Using the assumed number of rows, he expressed the number of chairs in the hall before and after the rearrangement. Secondly, he compared the numbers of chairs. Finally he justified his choice of the answer when he got two distinct solutions for the number of rows, one negative and the other positive. He differentiated between them, taking only the positive value and arguing that the number of rows could not take a negative value.

During the reflective interview, he revealed that he was also involved in imagining the context of the task when he realised that the task was not making sense to him:

Extract 9.5

R: … How did you come to realise how you were supposed to work it out?

S14: I had to give picture framework of the question. I gave a mental picture.

R: Can you describe it?

S14: I imagined first that the rows, there were 600 chairs. Each chair was supposed to accommodate one person that was also the time I was doing the second part of it, each chair was supposed to accommodate one person, yeah.

S14 imagined the arrangement of the hall and specifically the rows in the task, which helped him to make sense of the task. In his imagination he formed a picture framework of the hall with each chair accommodating one person. This picture framework was important because initially he considered that the chairs were benches. He came to terms with the fact that they were chairs and not benches.

Extract 9.6

S14: I was able to solve part (a) but when now it comes to part (b) I got a problem. So I had to again to imagine that each chair was supposed to accommodate one person. Initially when I was solving it I gave a wrong impression that they were benches, I took it in terms of benches. So when I took it critically I realised that these were chairs and every chair was supposed to accommodate one person.

A chair is generally taken to accommodate one person, as was the case in this task, but S14 first imagined a bench, which in essence accommodates more than one person. This misunderstanding gave him the wrong impression and he therefore experienced difficulties in interpreting part (b). He corrected himself, realising that the task was about chairs and not benches.

The activities and mode of argument explained above show that S14 participated in some practices that count as participation in competent mathematics Discourse.

Identity: S14 used the impersonal pronoun “we” throughout the extract. In doing so, he identified with the way language is used in the mathematics Discourse community (Pimm, 1987), solving the task as other mathematicians do. He therefore assumed a general identity, an identity that was stable throughout the extract.

Relationship: In using “we” throughout the extract, S14 is recognised as having a general relationship with other members in the mathematics Discourse community. The relationship was stable throughout the extract.

Politics: Identifying which method to use and differentiating the appropriate answer to the question were social goods worth having in responding to the task. S14 identified the quadratic formula method that could be used to solve for $\boldsymbol{r}$ in the quadratic equation so formed. He obtained two solutions: $\boldsymbol{r} = 20$ and $\boldsymbol{r} = -25$ and differentiated them, choosing $\boldsymbol{r} = 20$ as the number of rows.

Connections: S14 made connections to the mathematics register, formal mathematics language and valued mathematics Discourse practices (see e.g. Moschkovich, 2002; Pimm, 1987; Setati & Adler, 2000). In his explanation, S14 used constructions common in mathematics register, for instance “if…then…”, in making assumptions (see Pimm, 1987: 81), which in essence has logical implications. By making assumptions he connected his explanation to valued practices in mathematics Discourse. Furthermore, his claim of the number of rows involved differentiating between two possible solutions and justifying his choice, thus he connected his claim to valued mathematics Discourse practices. He used formal mathematics language throughout the extract.

Sign systems and knowledge: In Extract 9.4 above, S14 chose to use the quadratic formula in solving the task, although he was aware of other methods. Utterances in the extract show that he used English only in his communication with the researcher. However, the fact that he is trilingual could not be assumed and therefore I enquired whether he had used other languages in working out the task. His reflections earlier (see e.g. Extract 9.2) showed that he read some numerals in Kiswahili. In his verbal explanation of the solution of later sections, S14 used a few Kiswahili words such as "tuko na" [we have] and "itakuwa tu" [it will only be]. This was a practice he maintained throughout the reflective interview. His reflections indicated that he translated part of the task into his home language, Dholuo. This he did when he was correcting his mistake and reworking and completing the task. S14's switch to his third language is discussed below.

Extract 9.7

R: As you did that {solved}, were there other languages that were coming into play as you moved from one point to the other?

S14: Yeah, there was Kiswahili, some mother tongue[36] {laughs}.

R: Tell me more about how you involved them.

S14: I involved it {here he was referring to Dholuo as may be seen in the later utterances} at the stages where I was not able to interpret in terms of English.

R: Like which parts?

S14: I can go through it, "ama"? [or?]

R: Yeah, you can. {He reads the question and proceeds to interpret part of (b)}.

S14: In part (b) I had to involve, I was a bit confused in terms of these people {450} and the number of seats here. I had to involve Dholuo and Kiswahili so that I interpret that each chair was supposed to accommodate an individual. So depending on the equation that I got in part (b), I had to equate to the number of people so that I could solve it.

R: So did you translate the whole of part (b)?

S14: In mother tongue, yeah.

[36] Mother tongue is here used to refer to the home language

R: How did it go like? If you can write. {S14 writes the translation of part (b) in Dholuo}.

S14: "Ka ji 450 obedo to gi wuoyo kombe, kombe ma odong' onego bed ni ting'o ji 150". [If 450 are seated and they rearrange the chairs, the remaining chairs should accommodate 150 people] {He then read out the translation}. I set out the equation for the remaining chairs... {inaudible}.

R: And that assisted in getting the solution?

S14: Yes, because in stage (a) I was now having the equation, how I could put it so that I solve it for the number of empty chairs that was where there was a problem.

When I first asked him whether he used other languages, S14 laughed shyly. This was similar to the way in which S3 (in Chapter 8, section 8.2.3.1) and S13 (discussed later in section 9.3 below) reacted to my question on their use of other languages; this was probably an indication of how rarely issues related to other languages are discussed in mathematics classes at tertiary level. As indicated earlier in this section, S14 had some initial difficulties with (a); he reworked the task to completion and arrived at the expected solution. But it seemed the challenges posed by (a) did not require him to switch languages as he did in (b), where he had difficulties in the interpretation of the task and this caused some confusion. He needed to link the solution arrived at in (a) to the requirements of (b). In order to do so, S14 translated part of (b) into Dholuo and arrived at the solution for (b). From S14's account, it is clear that Dholuo was used as a linguistic resource when he faced interpretation challenges in English.

Discussion

The analysis above shows that S14 was convinced that the final equation that was required in solving the task was the quadratic equation. He participated in mathematics Discourse practices using formal mathematics language (Moschkovich, 2002; Setati & Adler, 2000). This was evident in his approach to the task when he set out the initial logical steps needed to arrive at the equation; first making assumptions about the number of rows and chairs and, secondly, making the necessary change to the numbers.

By choosing to use quadratic methods, he made these methods more valuable and privileged than other methods through which the particular task could have been solved. His choice of method resonates with the fact that when we choose to use one method and not another, we make that particular method more privileged than the other (see Gee, 2005, 2011a). He also differentiated between the answers obtained from solving the quadratic equations and gave justifications for his choice of answer.

In his explanation, his identity and relationship with others was transformed from that of an individual mathematician working alone to someone working and sharing information with other mathematicians. Thus at one point he worked as an individual while at other times he revealed solidarity with other mathematicians.

He used formal mathematics language and he connected his interpretation and solution process to valued practices in mathematics Discourse.

S14 used the three languages in his repertoire, Kiswahili, Dholuo and English, for different purposes. While he used mainly English in his verbal explanation and in all his written work, he asserted his claims in the interpretation in Kiswahili. However, it was observed that the words he used did not communicate mathematics itself; rather, they were words that supported his communication. In some later explanations he switched to some Kiswahili words, a practice which in my view was associated with the ease of using such words (see Planas, 2011). He had developed a habit of reading numbers of countable items in Kiswahili, which he associated with language use in his university residence. In the solution process, he mentioned that he was confused because of the difficulties in reinterpretation. He therefore switched and translated part of the task content to Dholuo in order to reinterpret the task and form the required understanding. This switching was an internal function, part of his thought processes.

S14's language practices therefore suggest that he was a student who, when faced with interpretation difficulties switched from English to Dholuo and read numbers of countable items in Kiswahili. Dholuo emerged as the dominant language that shaped his understanding when he was faced with interpretation challenges. It was a more reliable language resource than Kiswahili; it was his home language. His switching to Kiswahili, the national language, could be seen as to the result of his familiarity with certain words and numbers in Kiswahili, and not because of a lack of understanding of such words. Therefore, it was my view that S14's switch to Dholuo was spontaneous and reactive in solving the task, while the switch to Kiswahili was habitual.

His utterances contained cues and clues to mathematics register, formal mathematics language, conceptual mathematics discourse, code switching both verbally and in thinking, and valued mathematics Discourse practices.

9.2.2 Situated meanings and Discourse models at play

As the situated meanings associated with words and phrases are flexible and multiple, it was imperative that I understood the meanings that S14 associated with "hall" in the task:

Extract 9.8

R:	The question was about a hall; did you associate it with a hall somewhere?
S14:	Yeah, I had to.
R:	Tell me about it.
S14:	Church hall especially the Catholic Hall where we are staying {near hostels of residence}, I imagined such halls.
R:	Are there similar arrangements?
S14:	There are chairs, which are arranged {in} rows and columns.
R:	And did it assist you in doing the question?
S14:	Yeah, it assisted me in doing the question.

S14 lived in a hostel near the university. There were Catholic Church halls where university students often held meetings. These had similar arrangements to the hall in the given task and he imagined it in the context of these Catholic Church halls. While his image of the hall assisted him in solving the task, it was not a straightforward matter.

Initially, he assumed that the hall was furnished with benches and not chairs, which proved difficult for him to solve (see Extract 9.6 above). After realising that the task referred to chairs and not benches, chairs that accommodated one person each, he solved the problem.

The fact that S14 visualised the hall as a church hall may have facilitated his notion that the hall was furnished with benches (probably like pews) and not chairs. S14's situated meaning of a hall was applied against the Discourse model of a church hall, which was arranged like the hall in the task.

9.2.3 Emerging Discourse

From the discussion of S14's cues and clues in his social language and the situated meaning of a hall applied against the Discourse model of a church hall, S14 achieved the Discourse of a student who imagined the hall in the task as similar to a church hall and switched between the three languages in his repertoire in thinking and in verbal communication, while his written communication was in English. He combined and integrated the formal language of mathematics, valued mathematics Discourse practices and in most cases assumed the general identity of a mathematician and a general relationship with other mathematicians.

The next section comprises a discussion of the analysis of S13's language practices.

9.3 Analysis of S13's utterances in the interpretation and solution process

S13 was a 22-year-old student. He spoke Kikuyu more than he did Kiswahili or English at home with family members. Thus his home language was Kikuyu. All three languages were important for his individual engagement with mathematics; however, he switched between English and Kiswahili when discussing mathematics with his peers and lecturers. In KCSE he scored Grade A in mathematics and Grade B in English and he was enrolled for a degree in Civil Engineering.

9.3.1 Identifying cues and clues

a. In the interpretation

After S13 had read the task, I asked him what it required of him:

Extract 9.9

S13: The question first / you have to understand / what it is what it is talking about. The first thing it is talking about number of people that... {Rereads part of the question} …the number of chairs that can be accommodated in a certain room/. Then after understanding that point, then, ok the question is talking about how are these rows because these chairs they can't come just there, they are arranged in a certain order / {he gestures the arrangement of the rows using his hand}. This order, each row has the same number of chairs. Then after the number of the chairs, after the number of rows there is the ways the chairs are arranged in each row. Then the number of chairs is rearranged such that the number of rows is increased by five but the number of chairs per row is decreased by six. So I think the first thing is we can write the inform … {inaudible} interpret that information in a way that we can understand.

Table 9.3 Analysis of S13's utterances in the interpretation

Discourse situation	**Key words/phrases/actions**	**Indicators of patterns of cues and clues in the response**
Significance	... what it is talking about/ The first thing it is talking about how are these rows?'/ {he gestures the arrangement of the rows using his hand} /So I think the first thing is we can write the inform…{Inaudible} interpret that information in a way that we can understand	S13 makes understanding the content of the question significant.
Activity	The question first / you have to understand / what it is what it is talking about. The first thing… Then … how are these rows? because these chairs they can't come just there ... {he gestures the arrangement of the rows using his hand}. Then after… I think the first thing is we can write the inform…{Inaudible} interpret that information in a way that we can understand	S13 logically identifies the key points of the question that need to be understood prior to attempting the task. Gesturing about the arrangement of rows is important for him.
Identity	you have to /So I think the first thing/ we can write the inform…{Inaudible} / in a way that we can understand	He interprets the task alone and also in solidarity with other mathematicians, logically outlining the steps to follow.
Relationship	you have to /So I think the first thing/ we can write the inform…{Inaudible} / in a way that we can understand	A general relationship of working with other mathematicians is established here.
Politics	The question first /you have to understand /what it is what it is talking about. The first thing… Then after understanding that point, then… the question is talking about 'how are these rows?' /I think the first thing is we can write the inform…{Inaudible} interpret that information in a way that we can understand.	He makes understanding the task and setting logical steps for the interpretation social goods worth having at the initial stages of solving the task.
Connections	The first thing… Then after understanding that point, then/ Then after… the number of rows there is the ways the chairs are arranged in each row… I think the first thing is we can write the inform…{Inaudible} interpret that information in a way that we can understand	He is connecting the parts of the task one with the other in order to understand.
Sign System and knowledge	The question first / you have to understand / what it is what it is talking about. The first thing… each row has the same number of chairs….	His verbal explanation is in English only.

Significance: S13 made understanding of the task significant. This was evident when he posed a question about the rows and gestured the arrangement using his hands. He suggested that writing down the information from the task might help in understanding the task.

Activity: S13 set out logical steps to follow and gestured; practices that mathematically competent people engage in (see Khisty, 2006; Moschkovich, 2002, 2003). In order to make sense of the task he set out some logical steps that he could follow, and in the process he questioned and gestured the arrangement of the rows. Questioning and gesturing about the rows assisted him in refocusing on the task requirements. Making sense for him involved writing out the information from the task. S13 engaged with the activities of setting out logical steps, questioning and gesturing.

Identity: Using the pronouns "you", "we" and "I", S13 positioned himself differently in interpreting the task. He identified with other mathematicians in making sense and sharing his understanding of the task and he expressed an individual view of what ought to be done. His identity was not stable.

Relationship: S13 created a relationship by sharing information and suggesting his way of interpreting the task and later he related with other mathematicians from an individual perspective. His relationship with others was transformed from one of sharing information with other mathematicians, to one of an individual mathematician, and then back to involving other mathematicians.

Politics: Logical coherence was a social good worth having for him to attempt the task and in fact a prerequisite to the formulation and solution of quadratic equations, as is the case in the first-year algebra module he was taking. Logical coherence in mathematics is a necessary and acceptable practice in mathematics (see Moschkovich, 2002). Therefore, by setting out logical steps, S13 was participating in competent mathematical Discourse.

Connections: He connected the task content logically in order to understand it. His understanding was also connected to writing out the task information to facilitate interpretation.

Sign systems and knowledge: In extract 9.9 above, S13 gave a verbal interpretation of the task in English. When I enquired about his impression of the task during the reflective interview, he provided valuable information on how and why he used other languages:

Extract 9.10

> S13: For one, when you, the first part when I was reading it, when I was silent, I was trying to get is "what is the question trying to ask?" and I could visualise it in my own language, because / this language is not so…is not "haikuangi ati common kwa kila mtu" [it (English) is not common to everyone]. So at a certain point I could read the question if I have not understood then I try to figure out, "what does it mean?" If I'm given about this information, now I have to digest this information bit by bit in my own language. Then / from there after I have understood, after I have understood now the question, I could now be able in a position to write or answer the question.

S13 read the task in English, but thought through and imagined what was expected of him in his own language, particularly the parts he thought he did not understand. He switched to his own language because English was not his everyday language. He thought that the use of English was not just something he found difficult but also a difficulty for others since it is not a common language for everyone. By referring to the fact that English was not common to everyone, S13 could have been referring to the other (peer) students for whom English was neither a first language nor a home language. In this way English was positioned as a language for others, probably as the "they code" (see Chitera, 2009b). After having understood what the task required of him he could proceed to answer it. Thus in interpreting, S13 privileged his own language in his search for understanding and English for writing out and, of course, communicating with the researcher.

An enquiry into what his "own language" was and how it was used resulted in the following exchange:

Extract 9.11

R: You mentioned that you usually visualise it in your own language; what is this own language?

S13: Most of the time {laughing shyly} I usually, I usually… after I read a certain piece of question, I have to think it in my language now, my first language.

R: Which is your first language?

S13: My first language is Kikuyu {laughing shyly}, now after thinking in Kikuyu then I could now go to the question, now I have understood in a way that I can now react to the question what it is asking.

R: Does this always happen?

S13: Most of the time; if for example you can give me a question I lack to understand in a way that I can speak it in my own language, most of the time I will not be able to answer that question properly.

By his own language he meant his home language, Kikuyu. He used Kikuyu in the interpretation of the task. The use of this language was not unique to this task; it was a common practice for S13. He revealed that if he did not understand a question in Kikuyu, he would most likely not answer it correctly. This shows that while he read the tasks in English, he used Kikuyu for thinking and understanding. I asked how he used Kikuyu in this particular task:

Extract 9.12

R: In this question, did you do that throughout or it is in some parts that you had to engage in your first language?

S13: For example, in this part, I could read this one {referring to the first sentence in the question} I know what is talking about in my own language. Then after the first sentence then I continue {with all other sentences} then I can get the real picture of what the question is talking about. For example here, {reads the first sentence}. Now I could ask I could visualise in my mother tongue, "this is 600 / how could they be arranged? Yes they are in a room but how could they be arranged?" After I think it in my own ways now I come back to the questions after I have understood what is in me.

R: Is it something you can write?

S13: Yeah

R: Would you mind writing it?

S13: I write it in my own language? {R nods and S13 goes on to write the information part of the question in Kikuyu and then reads it aloud}.

Nyumba iganagira itĩ magana matandatu ibangitwo na mĩhari. Omũhari ukoragwa na itĩ ciganaine. Itĩ ni ciabangurirwo na ikibangwo ringĩ, na itĩ iria ciari muhari umwe ikĩnyiha na ithatatu na mihari ikiongerereka na ithano. [A house/building can accommodate 600 chairs arranged in rows. Every row has an equal number of chairs. The chairs were rearranged, and the chairs in each row reduced by six and the rows increased by five][37].

This is how now I understood the question in my own language. Now this is how I understood it in this format, after I understood it in this format, I could now translate this information in now in English, in my own way.

Although S13 had earlier indicated that he used Kikuyu when faced with challenges to his understanding, it seems he sought understanding of the whole task by translating it, sentence by sentence, into Kikuyu. In the part he wrote in Kikuyu, it is clear that a hall is referred to as "nyumba", meaning a house or building. This is because in the Kikuyu language there is no equivalent word for hall. The use of the term did not, however, cause any confusion for S13. He achieved the desired understanding of the task in Kikuyu then translated what he was writing into English. Up to this point, this trilingual student demonstrated how he switched between English and his home language, Kikuyu.

In his verbal explanation, he switched to Kiswahili, saying "kwa hivyo", here meaning "so that". In later utterances during the clinical interview, he used similar words and phrases, for instance, "ukuje useme [you say]" and "hapa [here]". While the meaning of the words does not reflect any translation of words in the task and their use did not suggest that S13 derived mathematical meaning from them, I took note of them because in my view he used them perhaps because of their familiarity and to support his

[37] While the translation is not word for word, it basically communicates the original message.

communication. While this use of Kiswahili was explicit, S13 explained that he also used it as a language of internal functioning, in other words thinking.

I explored how and why he had done so:

Extract 9.13

R: At certain times as you went along you used other languages.
S13: [Nods] Yeah, mostly I usually use Kiswahili.
R: How does it feature in your work, as you do it? I have record of four times that you are using Kiswahili {recap}. What role does it {Kiswahili} play {in responding to the task}?
S13: This one maybe after understanding it in this way {in reference to the Kikuyu translation}, because Kiswahili is the language which is closer to my language, now I come to use it severally.
R: When you are talking or when you are doing the work itself?
S13: When I'm working, especially when I'm working. If it's come on mathematics or maybe sciences, I will have to think in those two languages, I read in this one {English}, then in the process I will come now to use this Kiswahili in the meanwhile.

In thinking, he used Kiswahili only after he had gained understanding in Kikuyu, because Kiswahili is close to Kikuyu[38], his home language. It is my view that this closeness suggests that he was more fluent in Kiswahili than in English. Although in Extract 9.13 above his initial statement on the use of Kiswahili implies uncertainty, subsequent utterances make it clear that it is not only in mathematics that he switches to Kiswahili, but also in science. So if initial understanding in Kikuyu precedes the use of Kiswahili, then it is clear that the Kikuyu language was used more than Kiswahili in seeking understanding, implying that his home language was privileged in interpreting the task.

S13 positioned himself as a student who used three languages in interpreting the task. He used the languages not only in mathematics but also in science. We see some complexity in how and why he used both Kikuyu and Kiswahili after understanding the

[38] Kenya's languages generally belong to three families, the Bantu, the Cushites and the Nilotes. Both Kiswahili and Kikuyu belong to the Bantu family, and some words are closely related in spelling, meaning and pronunciation.

task in Kikuyu reflected in his statement “I will have to think in those two languages”. It is not clear whether this occurred in a mixture of Kiswahili and Kikuyu or whether there was a distinction between their functions prior to translating back to English for reporting purposes.

S13 is therefore recognised as a student who reads the task in English, interprets it in Kikuyu, and then perhaps uses Kiswahili before translating back into English for reporting purposes. Switching to Kikuyu to seek conceptual understanding made this the dominant language shaping S13’s understanding of the task.

b. In the solution process

In the knowledge that S13 had used his three languages in the interpretation of the task, I then analysed his language practices in the solution process[39]. In solving the task, S13 made some mathematical errors in the formulation of the quadratics equation (omitting one value and wrongly changing signs) (see worksheet in Appendix K). He realized and corrected and proceeded to work out the expected solution. In the whole process, S13 made assumptions and justified them. He used both informal and formal mathematics language to express and operate the mathematical expressions so formed. He made connections within the task and also connected the task to the mathematics register and conceptual mathematics Discourse. He identified and related to members of the mathematics community, thus assuming a general identity and relationship. He switched languages from English to a few Kiswahili words, not because he needed to translate the words to derive meaning from them but because of the ease with which he used such words in Kiswahili. In short, S13 generally used English in solving the task.

[39] The language practices were to a large extent similar to those that were recognized during the interpretation process, or were a follow up, similar to those of other students. Therefore in this sub-section I present a summary.

Discussion

S13 made understanding the task significant and worthwhile. He engaged with practices that reflected his participation in mathematics Discourse practices (see Moschkovich, 2002), using both formal and informal mathematics language. This was evident in the logical steps that he set out to follow in solving the task. Furthermore, he questioned and gestured as to the arrangement of the chairs and he made assumptions and justified these. He identified with members of the mathematics Discourse community in that he approached the task as a mathematician would; at once as an individual mathematician and in solidarity with other participants in mathematics community (see Pimm, 1987; Rowland, 1999). Subsequently, his relationship with other mathematicians was at times detached and at others associated with the mathematics community. S13 systematically connected the task content in order to understand it, which in turn was connected to writing out the task information in order to facilitate interpretation.

S13 used all the three languages in his language repertoire as he interpreted the task, English, Kikuyu and Kiswahili. He translated the whole task into Kikuyu to understand it. Having formed this understanding, he then switched to Kiswahili and finally to English for reporting purposes. S13 not only switched and translated the task content into either of these two languages; this was a common practice in his other tasks and in the sciences. He positioned English as the language for others, the "they code" (see Chitera 2009b).

In summary, S13's utterances contain cues and clues to individuality as well as working with other mathematicians in the mathematics community, code switching between any two languages in his trilingual language facility, formal and informal mathematics language, mathematics register, gesturing and conceptual mathematics discourse, and valued mathematics Discourse practices.

9.3.2 S13 Negotiating the situated meaning of key word

S13 situated the meaning of "hall" in the university auditorium; in fact, he explained that the auditorium was his first thought and image of a hall. This is similar to how S8 situated the meaning of "hall" (discussed in Chapter 8 section 8.2.1.2). His experience of an auditorium was evident in his explanation that the rows were not of the same length. His image of a hall as an auditorium informed his meaning of "hall" in the task and served to facilitate the interpretation and subsequent solution of the task. Therefore S13 situated the meaning of hall and applied it against the Discourse model of an auditorium.

9.3.3 Emerging Discourses

S13 can thus be recognised as having "pulled off" a Discourse in which he combined and integrated his verbal utterances and gestures, working either as an individual mathematics student or with others in the mathematics community, making assumptions and forming images of a hall as an auditorium in order to make sense of the hall and the arrangement of chairs in the task. Furthermore, he switched between his three languages, with his home language being the dominant language in his interpretation of the task, using English for solving and generally reporting on the task.

9.4 Findings on language practices involving three languages

The two students whose language practices involved the use of three languages in their repertoire revealed that they used languages in various ways to interpret and solve the task. In interpreting the task, S14 and S13 switched between English and their home languages, Dholuo and Kikuyu respectively. They switched to think through and seek understanding of the task. The switching involved translating whole sentences or the whole task into the respective language.

Both S13 and S14 switched to Kiswahili in their verbal explanations because of their ease with the use of some words in this language and not necessarily to derive meanings of words; in fact, the words were used for non-mathematical reasons. S14 switched to his home language, Dholuo, when he was faced with interpretation challenges, while Kiswahili was used habitually throughout to read numbers of items. S13 relied on Kikuyu when he needed to understand the task. He used Kiswahili after having gained understanding in Kikuyu. Therefore the home languages of the two students were the dominant languages used in interpreting and understanding the task, while Kiswahili functioned to give support to their communication and to some extent to the understanding gained from the task. In the solution process, English emerged as the dominant language for both students. They used it in thinking, writing and in most of their verbal utterances.

S13 and S14 positioned themselves as individual mathematicians interpreting and solving the task, while at other times they worked in solidarity with other mathematicians in interpreting and solving the task. This was evident in the way they used the pronouns “I”, “you” and “we”.

They set out logical steps to interpret the task, made assumptions and provided justifications for their work. S14 also justified his choice of the answers he arrived at. These are attributes of participation in mathematics Discourse practices and conceptual mathematics discourse (Moschkovich, 2002; Sfard, et al., 1998). Furthermore, both students connected their arguments to a particular aspect of algebra; S14 to the quadratic equation and S13 to the formation of simultaneous equations.

They both used formal mathematics language in both the interpretation and the solution process. S13 also used informal mathematics language in his solution process. They also both used language to connect their explanation to valued mathematics Discourse practices. S13 gestured about the arrangement of rows of chairs.

Thus in interpreting and solving the task, both S13 and S14 participated in mathematics Discourse practices.

9.5 Conclusion

In this chapter, I provided the analysis of the language practices of two trilingual undergraduate students whose language practices involved all three of their languages. Findings show that both students participated in mathematics Discourse practices and used their three languages according to their communication needs. They read the task in English and then switched to their respective home languages to translate the task to improve their understanding. This happened in the interpretation of the task but not necessarily in the solution process. Both students used Kiswahili throughout the task and one of them also used it after the translation into his home language. Furthermore, Kiswahili was used for non-mathematical purposes, serving to support the students' communication. In the solution process, the students communicated their ideas mainly in English. In writing, the students used English but the verbal explanation was provided in both English and Kiswahili. Thus in view of the interpretation and solution process, the home languages emerged as the dominant languages in the interpretation of the task while English was revealed as the dominant language in the solution process. Kiswahili emerged as the language that supported their communication. The students situated meaning of the word "hall" according to their individual experience of halls in their particular contexts, and applied these against their individual Discourse models to sense of the task.

The next chapter comprises a recap of the study, a summary of the findings discussed in Chapters 7, 8 and 9, recommendations and the conclusion to the study.

CHAPTER 10

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

10.1 Introduction

At the beginning of this study, I set out to explore whether, how and why trilingual undergraduate students use their languages to make sense of mathematics. I stated that my motivation in undertaking this research was based on my experience as a student and as a teacher whose home language was not the LoLT, and who succeeded in mathematics but whose performance in the LoLT was wanting. My focus on the language practices was further intensified by UNESCO's (UNESCO, 1974) call for research in contexts where the language of instruction is not the students' first language considering that such students may relate mathematical tasks to their first languages. Studies conducted in mathematics education in bilingual and multilingual contexts (see e.g. Adler, 1998; Moschkovich, 1999, 2002; Setati, 2005) have shown that while teaching may take place in a LoLT that is not the students home language, such students draw on their home languages to make sense of mathematics problems. In the case of Kenya, where students become trilingual through schooling, research has been conducted on teaching perspectives that focus on the use of two languages by students (Bunyi, 1997; Cleghorn, et. al, 1989; Merrit, et al, 1992). To my knowledge, no research has been conducted that deals with mathematics education in trilingual contexts; in fact, in her recent work, Phakeng (2013) identified this research gap. Thus a combination of my experience and the findings from literature led to my interest in researching language practices in mathematics among trilingual students who are competent in mathematics. In particular, how undergraduate mathematics trilingual students use their languages to engage with mathematics tasks.

This chapter presents a recap of the research process, a summary of the findings and the contributions made by the study, recommendations, limitations and the conclusion.

10.2 Recap of the research process

This study focused on how trilingual students position themselves when engaging with mathematics tasks in mathematics Discourse and in their respective home languages, the national language Kiswahili, and the LoLT, English. The study was guided by the following research questions:

1. How do some trilingual undergraduate students in a Kenya use their languages when solving mathematics tasks?
2. What language practices do these trilingual undergraduate students use when engaging with given mathematics tasks?
3. Why do these students use their languages as they do?

In order to address these questions, I posed sub-questions as in Table 6.2, which enabled data collection and analysis. In collecting the data, I adapted qualitative research processes and in particular the case study approach. I sampled the universities and students and focused on Procity University and trilingual undergraduate students of three degree programmes which had mathematics as courses. Initial data was collected using questionnaires and 15 students were selected. Further data was collected from these students using clinical and reflective interviews with each student. I transcribed the interviews and 11 paired transcripts from the clinical and reflective interviews that illuminated responses to my research questions were analysed. Of these transcripts, five were analysed in detail, focusing on the interpretation and first part of the solution process. The analysis followed the theoretical construct of Discourse analysis (Gee, 2005). In order to identify the various social identities and activities that the trilingual students enacted in their workings, social languages, situated meanings, Discourse models and Discourses were used to ask certain questions about the seven Discourse situations. The identities and activities so identified helped me to understand the students' language practices.

10.3 Summary of findings

The major findings of the study were that in their language practices, trilingual undergraduate students identified with mathematics Discourse and with the use of English only, English and home language or English, home language and Kiswahili. Of the 11 students whose transcripts were analyzed, nine of them spoke home languages that were also their first languages, while two used Kiswahili as their home language although it was not their first language. Other home languages of these students were Kikamba, Kikuyu, Dholuo, Ekegusii and Luluhya. The language(s) used by trilingual students in this study in verbal communication, writing and thinking in relation to their social culturally defined experiences shaped the identities they enacted using their trilingual language facility and the activities they were engaged in within mathematics Discourse.

During the engagement, students participated in valued mathematics Discourse practices. These were evident in all the language practices involving one or more of their languages. These involved students in:

- Making assumptions, identifying variables, forming both simple and quadratic expressions, with some justifying what they did.
- Approaching the task and constructing sentences, which were rich in terms and modes of argument as mathematics register and mathematics Discourse practices.
- Solving quadratic equations using the quadratic formula.

- Communicating their mathematics ideas using gestures, mathematical representations in the form of sketches, everyday experiences, home languages and code switching.

They presented their work logically. Both formal and informal mathematical languages were evident in their utterances. Their approach and way of working as well as the use of pronouns positioned all the students as individuals as well as members of the mathematics Discourse community, thus they assumed individual as well as general identities and relationships. Those who completed the task correctly were able to differentiate the solutions that emerged (negative and positive) and apply them accordingly. All students had acquired control over the mathematics register, engaging with either conceptual or calculational mathematics discourses and in general they participated in mathematics Discourses using either one language or by switching between languages.

10.3.1 Language practices involving English language only

Three students used English only in the task. One student did so for two main reasons: mathematics had been taught and presented to him in English only, and because he found the language used in the task understandable. The other two students used English only because they also found the language that was used in the task to be understandable. These findings in a trilingual context are consistent with earlier findings in bilingual contexts, where students did not switch between their languages as they engaged with mathematics (Clarkson, 2006; Moschkovich, 1996; Ndayipfukamiye, 1994; Parvanehnezh and Clarkson, 2008). The findings from this study confirm Hoffmann's (2001) suggestion that trilingual students may use one language the way monolinguals do. What is unique about this finding is that the students were trilingual and yet they expressed monolingual behaviour when they engaged with a mathematics task in ways that resonated with mathematics Discourse practices. They kept to the LoLT, English, in reading, interpreting, solving and reporting the task both verbally and mentally.

10.3.2 Language practices involving two languages

The analysis of the language practices involving two languages, that is English and students' home languages, included six students. The findings showed that the students participated in mathematics Discourse practices. Code switching between English and their home languages was a mental practice. They switched to translate parts or the whole task because of their familiarity with their home languages. In particular, S4 switched because he found it difficult to understand part of the task in English while S3 switched because he needed to form a better understanding of the task. For these students, code switching occurred in the interpretation of the task and not in the solution process. S8, S6, S10 and S15 translated the whole task and did so whenever they encountered mathematics tasks.

The two languages had different functions: the home language was for translating and exploring meaning mentally and English was for verbal and written communication with the researcher. Furthermore, S3, S4 and S8 believed that English was the language for formal communication and hence they used it when they engaged with the researcher. This positioned English as the more powerful language of communication in this context. Thus, while the students' home languages were not the LoLT in mathematics teaching and learning, they were used as resources by the students as they engaged with the algebra task. These trilingual students used two languages in their repertoire in much the same way as bilingual students (see e.g. Moschkovich, 1999, 2002; Planas & Civil, 2008; Planas & Setati, 2009) and multilingual mathematics students (see e.g. Adler, 1998; Setati, 2005); in fact, in keeping with Hoffmann's (2001) observation that trilinguals may use two languages in their repertoire in the same way as as bilinguals.

10.3.3 Language practices involving three languages

The language practices of two students involved three languages that were the LoLT, their home languages and Kiswahili. These students switched between English and their home languages, Dholuo and Kikuyu, to think through and understand the task. The switching occurred when they translated whole sentences or the entire task into their respective home languages. This switching was aimed at interpreting the task and not necessarily at solving it. They switched to Kiswahili in their verbal explanations as a result of the ease associated with the use of some words in that language but not necessarily to derive the meanings of any particular words. Such words were used for non-mathematical reasons; in fact, these words served to support students' communication. S14 habitually switched to Kiswahili to read numbers while S13 switched to Kiswahili after having understood the task in Kikuyu.

The home languages of the two students were the dominant languages in the interpretation and understanding the task, while Kiswahili functioned to give support to their communication. In the solution process, English emerged as the dominant language; both students used it in thinking, writing and in most of their verbal utterances. The languages were not used equally.

In conclusion, it was found that the students' language practices involved approaches that are commonly used in mathematics Discourse; a common thread for the majority of students was their code switching between their home language and the LoLT. This code switching happened for a range of purposes:

- To translate the task: the students translated parts or the whole task into their respective home languages because they were so familiar with these, to emphasise certain words or to form a better understanding of the task.
- Due to ease associated with using a language
- As a result of the context in which the students found themselves.

The home languages and the LoLT also had different functions: the LoLT was used for communication with the researcher in both verbal and written forms, while home languages were used in the interpretation of the task. The students whose language practices involved three languages switched to Kiswahili because of their familiarity with it and to express their identities.

All students who switched between languages made a conscious effort to translate mentally and verbally what they read in English into their home languages. Their trilingualism facilitated their flexibility in expressing the task in different languages in ways that were similar to researchers' observations of bilinguals (see e.g. Ianco-Worrall, 1972; Peal and Lambert, 1962 in Carringer, 1974). It is clear that code switching filled a momentary linguistic need and was a useful communication resource for the trilingual students. In fact, these students' switch to their home languages provided access to mathematics and supported the finding that home languages are resources that aid students' understanding of mathematics (see e.g. Setati et al., 2008). English was positioned as a powerful language that was used to communicate in official settings such as the interview sessions in this study. It was regarded as a "they code" while home languages functioned as "we codes". In general, all eleven students in this study used languages as monolingual, bilingual or trilingual students do.

The findings show that whenever code switching was used the three languages were not used simultaneously; rather it was generally a switch from the LoLT to other language and back to LoLT for reporting purposes. The code switching situations that stand out in this study and that relate to mathematics are; when the student is faced with interpretation challenges, when he/she needs to emphasise a point and due to habitual practices of switching. The key reason for code switching is to gain understanding. On the other hand, a trilingual student is likely to remain in the LoLT because content has been taught and presented a task in the LoLT.

10.4 Contributions of the study

The contributions of this study are addressed in relation to the study's rationale as discussed in Chapter 1, section 1.5. English, Kiswahili and the students' home languages have been positioned in a range of LiEPs that have been implemented in independent Kenya. The study argues that while Kiswahili was recently upgraded to an official language, its implementation as LoLT has yet to be realised. English has in effect remained the dominant language in LiEP. Furthermore, home languages that are indigenous languages are not taught as subjects nor used legally as the LoLT after Standard Three. The result is that home languages have been academically subtracted from the students' language repertoire.

In the light of the above, this study established that when engaging with a mathematics task, some students kept to the LoLT, others switched between English and their home languages while others still switched between English, Kiswahili and their home languages. This switching occurred in students' solitary engagement with the task; for they switched in thinking while interpreting the task or in their verbal communication with the researcher. The fact that they mentally engaged their mathematics in other languages was most unexpected because these students had learnt mathematics in English over the previous nine years; as in Clarkson's (2006) study, one would have expected them to have mastered the LoLT to a degree that made switching between codes unnecessary. In addition, their mathematics grades did not suggest that they were struggling to understand mathematics presented in English. Thus this study has made a contribution to the field by establishing that code switching is not the preserve of students who are learning the LoLT; rather, code switching is a reality in mathematics, even for trilingual undergraduate students who are competent in the LoLT.

The students in this study identified with the languages that they used. The majority positioned their home language as the dominant language that facilitated interpretation and understanding of the task. Kiswahili supported their communication and helped them to express their identity and English was dominant in the initial reading, verbal reporting and writing. Thus Kiswahili and the home languages had a social value and worth in students' interpretation, understanding and communication of the task. Kiswahili should thus not be regarded merely as a language subject or as the lingua franca among heterogeneous language communities, but rather as a language that supports students' communication. In the same way, home languages should not be viewed as languages that students use in their home environments only, but as languages that they rely on for interpretation and understanding of mathematics tasks. In summary, the students' perception that English is the official language of engaging and communicating mathematics and about mathematics resonates with the dominance of English as the LoLT expressed in the LiEP. The findings of this study clearly show that while English and Kiswahili are official languages in Kenya, they do not have equal power and status in education.

The rationale stemmed from recent research in mathematics education and language diversity highlighted the need to carry out this study in the present context. The fact that no research on language practices among trilingual students has been conducted makes this study significant. Literature reviewed in this study showed that research in bilingual and even in multilingual contexts (e.g. Chitera, 2009a, 2009b; Setati & Adler, 2000; Setati & Planas, 2012) has focused mainly on students' home languages and the LoLT.

The current study focused on trilingual language facility by including the national language Kiswahili, home languages and the LoLT. That trilinguals have specific ways of using their three languages (Hoffmann, 2001), has been demonstrated in this study. That is, they are able to function like monolinguals, bilinguals or even trilinguals. This study has provided insights into whether, how and why trilingual students use their languages as they do when engaging with mathematics tasks. Since trilingual speakers are considered as a special case among multilingual speakers, the findings of this study have helped to broaden the view of the language practices of multilingual students already investigated.

Research in mathematics education on bi/multilingual language practices has commonly been concentrated at primary and secondary level (Bunyi, 1997; Planas, 2011; Setati, Adler, Reed & Bapoo, 2002) with some exceptions at college level (Chitera, 2009b). The study reported in this thesis was conducted at university level and is probably the first study on trilingual language practices at university level. The findings will inform mathematics lecturers on what transpires linguistically in their trilingual students as they engage with mathematics tasks.

10.5 Recommendations

The recommendations made address the LiEP in Kenya and research into mathematics education in general. The mathematics Discourses that were at play in this study show that the students generally engaged with acceptable procedures in solving the task and switching (or not) between their three languages. The indigenous languages and Kiswahili were positioned as language resources for engaging with mathematics tasks even when the former had not been used educationally beyond Standard Three. The LiEP, however, positions English as the dominant and legal language of teaching and learning in post lower primary classes. Furthermore, there is a monolingual LoLT policy at university level, with no space for Kiswahili or the indigenous languages. This study found that these languages were used by undergraduate trilingual students to interpret mathematics tasks. This means that Kiswahili is not only widely used in social communication, as the lingua franca, but also that it is a language that students are suitably familiar with to switch to when interpreting and seeking understanding of mathematics tasks, both in peer group discussions and in solitary moments of engaging with mathematics. Thus the question that I posed in Chapter 1 (section 1.5.1.2) and that requires further research is whether there is the possibility in the future of Kiswahili being used as the LoLT. Since it is an official language, it should be functionally positioned as an official language of learning and teaching. By extension, potential teachers of mathematics should be competent not only in English but also in Kiswahili. Kiswahili and students home languages should be used as resources to support students' exploration, understanding and communication of the meaning of mathematics.

Five trilingual students in this study claimed that they had translated the whole task, and in fact for most of them such translation was a common practice. All but one of the students arrived at the correct solution. There were no indications that they faced translation challenges or misconceptions. However, research shows that translation of all content may present difficulties since some of the terms in mathematics may either be unavailable in home languages or not commonly used (Setati, 1998). Furthermore, translation does not always work to the advantage of students (Kern, 1994); if content is inaccurately translated it may lead to misconceptions. What then does this finding on whole task translation mean for research? It suggests that there is certainly a need for further research in code switching for translation purposes.

Hoffmann (2001) conducted research on how language learners acquire trilingualism and how they use the three languages in their repertoire. This study has conducted research on how trilingual undergraduate students of mathematics use their three languages and has found that six of eleven trilingual students switched between two languages. This finding suggests that there is no difference in the way trilingual and bilingual students use languages. However, two other students used their three languages and three others kept to the LoLT. These findings show that the three languages in the students' repertoires do not have equal importance when engaging with mathematics. The findings also revealed that the trilinguals in this study were competent speaker-hearers by the standards of their linguistic environment and communication requirements, which supports observations by Hoffmann (2001). Taking into account that research on trilingual mathematics students' use of three languages is in the early stages, further research is recommended to gather more evidence on the language practices of such students in a range of linguistic and geographical environments, particularly when they are use their three languages in learning and teaching.

10.6 Limitations of the study

The trilingual students were provided with the opportunity to express their interpretation and understanding of the solution process in different languages. However, some students felt reluctant to code switch as a result of the context. This group of students, in my view, did not feel that they were entirely permitted to express themselves verbally or in writing in languages other than the LoLT. This indicates that the students limited themselves in their expression of their mathematical understanding and hence limited the findings of the study.

10.7 Conclusion

My quest to understand the language practices of trilingual students who were competent in mathematics was achieved in this study. While my initial idea focused on students who were not competent in the LoLT, an exploration of undergraduate students undertaking degree programmes and whose prerequisite subjects did not include English revealed that the students were also competent in the English language, that is, the

LoLT. The study has revealed that the language practices of these students as they engaged with the mathematics task involved their identification with valued mathematics Discourse practices, using their trilingual language facility in complex ways. There were instances of code switching (or not) at different stages of working on the task. Code switching happened in solitary moments of engaging with mathematics and in peer discussion groups. More specifically, this study has shown that competence in the LoLT is not sufficient for engaging with mathematics in the LoLT only; rather, the home languages and the national language are resources that play a key role in supporting students' interpretation and understanding, and also the verbal and mental processing of the solution. The findings point to students' personal initiatives in exploring meaning in the other languages in their repertoire.

Based on my findings, I have made recommendations on Kenya's LiEP and suggested the direction for future research.

REFERENCES

Adler, J. (1997). A participatory-inquiry approach and the mediation of mathematical knowledge in multilingual classrooms. *Education Studies in Mathematics,* vol. 33: 235–258.

Adler, J. (1998). A language of teaching dilemmas: unlocking the complex multilingual: secondary mathematics classroom. *For Learning Mathematics*, vol 18 (1): 24–33.

Arthur, J. (1994). English in Botswana primary classrooms: functions and constraints. In C.M. Rubagumya, *Teaching and researching language in African classrooms.* Clevedon: Multilingual Matters. pp 63-78.

Arthur, J. (1996). Code switching and collusion: classroom interaction in Botswana primary schools. *Linguistic and Education,* vol. 8: 17–33.

Baker, C. (1993). *Foundations of bilingual education and bilingualism.* Clevedon, Avon: Multilingual Matters.

Barton, B. & Neville-Barton, P. (2003). Investigating the relationship between English language and mathematics learning. *European Research in Mathematics Education*, vol. III: 1–10.

Barwell, R. (2003). Patterns of attention in the interaction of a primary school mathematics student with English as an additional language. *Educational Studies in Mathematics*, 8(4): 313–327.

Best, J. & Khan, J. (1998). *Research in Education.* Boston: Allan and Bacon.

Bogdan, R.C. & Biklen, S.K. (1992). *Qualitative research for education: an introduction to theory and method*. London: Allan and Bacon.

Bunyi, G. (1997). Multilingualism and discourses in primary school matheatics in Kenya. *Language, Culture and Curriculum*, 10(1): 52–65.

Carringer, D.C. (1974). Creative thinking abilities of Mexican youth: the relationships of bilingualism. *Journal of Cross-Cultural Psychology*5(4): 492–504.

Chilora, H. G. (2000). School language policy, research and practice in Malawi. *Paper presented at the Comparative and International Education Society (CIES)*, San Antonio, Texas, USA, pp. 1–10.

Chitera, N. (2009a). Code-switching in a college mathematics classroom. *International Journal of Multilingualism*, 6(4): 426–442.

Chitera, N. (2009b). *Dicourse practices of mathematics teacher educators in initial teacher training colleges in Malawi.* Unpublished doctoral thesis, University of Witwatersrand, Johannesburg, South Africa.

Civil, M., & Planas, N. (2004). Participation in mathematics classroom: does every student have a voice? *For the Learning of Mathematics*, 24(1): 7–12.

Clarkson, P. (1984). Language and mathematics in Papua New Guinea: a land of 720 languages, in Southwell, B., England, R., Cooper, M., Conroy, J. and Collins, K. (Eds). *Proceedings of the 8th Conference of International Group for the Psychology of Mathematics Education*, Sydney, Australia, pp. 331–338.

Clarkson, P. (1992). Language and mathematics: a comparison of bilingual and monolingual students of mathematics. *Education Studies in Mathematics*, vol. 23: 417–429.

Clarkson, P. (2003). Australian Bilingual Students and Mathematics. *European Research in Mathematics Education III; Thematics Group 10*: 1–8.

Clarkson, P. (2005). Two perspectives of bilingual students learning mathematics in Australia: a discussion, in D. Hewwit & Noyes, A. (Eds). University of Warwick, pp. 33–40.

Clarkson, P. (2006). Australian Vietnamese students learning mathematics: high ability bilinguals and their use of their languages. *Educational Studeies in Mathematics*, vol. 64: 191–215.

Clarkson, P.C. (1996). NESB migrant students studying mathematics: Vietnamese and Italian students in Melbourne. *Proceedings of the 20th Conference of the*

International Group for the Psychology of Mathematics Education, 2, Valencia, Spain, July 8-12. 2: pp. 225–232.

Clarkson, P. & Galbraith, P. (1992). Bilingualism and mathematics learning: another perspective. *Journal for Research in Mathematics Education*, 23(1): 34–44.

Cleghorn, A., Merrit, M. & Abagi, J.O. (1989). Language policy and science instruction in Kenyan primary schools. *Comparative Education Review*, 33(1): 21–39.

Cohen, A. (1995). In which language do/should multilinguals think? *Language, Culture and Curriculum*, 8(2): 99–113.

Creswell, J. (1994). *Research designs: qualitative and quantitative approaches*. Thousand Oaks, Calif: Sage.

Creswell, J.W. (2009). *Research design: qualitative, quantitative, and mixed methods approach*. Los Angeles: Sage.

Creswell, J.W. (2012). *Research design: qualitative, quantitative and mixed methods approach*. Los Angeles: Sage.

Cummins, J. (1979). Linguistic interdependence and the educational development of bilingual children. *Review of Educational Research*, 49(2): 222–251.

Cummins, J. (1981). The role of primary language development in promoting educational success for language minority students. In *Schooling and language minority students: A theoretical framework.* Los Angeles: Evaluation, Dissemination and Assessment Center, California State University, Los Angeles.

Cummins, J. & Mulcahy, R. (1978). Orientation to language in Ukrainian-English bilingual children. *Child Development*, 49: 1239–1242.

Daily Nation Newspaper. (20th Dec 2012). Nairobi: Nation Media Group Limited.

Daily Nation Newspaper. (10th June 2011). Nairobi: Nation Media Group Limited.

Dawe, L. (1983). Bilingualism and mathematical reasoning in English as a second language. *Educational Studies in Mathematics*, vol. 14: 325–353.

De Courcy, M. & Burston, M. (2000). Learning mathematics through French in Australia. *Language and Education,* 14(2): 75–95.

Dlamini, C. (2009). An investigation into mathematics high achieving Nguni learners with limited English proficiency. Johannesburg, South Africa: Unpublished doctoral thesis, University of the Witwatersrand.

Dominguez, H. (2011). Using what matters to students in bilingual mathematics problems. *Educational Studies in Mathematics*, vol. 76: 305–328.

Downing, J. (1974). Bilingualism and learning to read. *Irish Journal of Education*, 8(2): 77–88.

Drouhard, J. & Teppo, A.R. (2004). Symbols and language. In K. Stacey, H. Chick & Kendal, M. *The future of the teaching and learning of Algebra,* New York: Kluwer Academic Publishers, pp. 225–264.

Eshiwani, G. (1993). *Education in Kenya since independence.* Nairobi: East African Education Publishers.

Farrel, M. (2011). Bilingual competence and students' achievement in physics and mathematics. *International Journal of Bilingual Education and Bilingualism,* 14(3): 335–345.

Forman, E.A., McCormick, D.E. & Donato, R. (1998). Learning What counts as a mathematical explanation. *Linguistics and Education,* 9(4): 313–339.

Gee, J.P. (1996). *Social linguistics and literacies: ideology and discourses.* London: Taylor and Francis.

Gee, J. P. (1999). *An introduction to Discourse Analysis: Theory and method* (First ed.). London: Routledge.

Gee, J. P. (2005). *An introduction to Discourse analysis:Theory and Method* (Second ed.). London: Routledge.

Gee, J.P. (2011a). *How to do a discourse analysis: theory and method.* London: Routledge.

Gee, J.P. (2011b). *How to do discourse analysis: a toolkit.* New York: Routledge.

Gerber, A., Engelbrecht, J., Harding, A. & Rogan, J. (2005). The influence of second language teaching on undergraduate mathematics performance. *Mathematics Education Research Journal*, 17(3): 3–21.

Gerofsky, S. (1996). A linguistic and narrative view of word problems in mathematics education. *For the Learning of Mathematics,* 16(2): 36–45.

Gorgorio, N. & Planas, N. (2001). Teaching mathematics in multilingual classrooms. *Educational Studies in Mathematics*, vol. 47: 7–33.

Grosjean, F. (1982). *Life with two languages.* Cambridge, MA: Havard University Press.

Grosjean, F. (1985). The bilingual as a competent but specific speaker-hearer. *Journal of Multilingual and Multicultural Development*, 6(6): 467–477.

Guba, E.G., & Lincoln, Y.S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y.S. Lincoln, *Handbook of qualitative research*, London: Sage Publications, pp. 105–117.

Halliday, M.A. (1973). *Explorations in the functions of language.* London: Edward Arnold.

Halliday, M.A. & Hasan, R. (1989). *Language, context, and text: aspects of language in a social-semiotic perspective.* Oxford: Oxford University Press.

Heugh, K. (2009). Contesting the monolingual practices of a bilingual to multilingual policy. *English Teaching: Practice and Critique*, 8(2): 96–113.

Hitchcock, G. & Hughes, D. (1995). *Research and the teacher: a qualitative introduction to school based research.* London and New York: Routledge.

Hoffmann, C. (2001). Towards a description of trilingual competence. *International Journal of Bilingualism*, 5(1): 1–17.

Howie, S.J. (2003). Language and other background factors affecting secondary pupils' performance in mathematics in South Africa. *African Journal of Research in Science, Mathematics & Technology Education*, vol, 7: 1–20.

Ianco-Worrall, A. D. (1972). Bilingualism and Cognitive Development. *Child Development*, *43*(4): 1390-1400.

Joint Admissions Board (JAB). (2010). *Revision of degree programs*. Nairobi: Avaliable online: http://jab.uonbi.ac.ke [Accessed 2010, 1 October].

Jomo Kenyatta University of Agriculture and Technology (JKUAT): Faculty of Engineering. (2008). Syllabus for the Degree of Bachelor of Science in Mechatronic Engineering (8–4–5 programme).

Kazima, M. (2006). Malawian students' meaning for probability vocabulary. *Educational Studies in Mathematics*,vol. 64: 31–43.

Keats, D.M. (1997). Interviewing for clinical research. In J.P. Keeves, *Education research, methodology, and measurement: an international handbook*, New York: Pergamon, pp. 306–310.

Ministry of Education. (2002). *Ministry of Education secondary education syllabus*. Nairobi: Kenya Institute of Education.

Kenya National Bureau of Statistics. (2010). *2009 Population and Housing Census Results.* Nairobi: Kenya National Bureau of Statistics.

Kern, R.G. (1994). The role of mental translations in second language reading. *SSLA*, vol. 16: 441–461.

Khisty, L.L. (2006). Language and mathematics: towards social justice for linguistically diverse students. *Proceedings of the 30th Conference for the International Group for the Psychology in Mathematics Education*, *3*, pp. 433–440, Prague, PME.

Khisty, L.L., McLeod, D.B. & Bertilson, K. (1990). Speaking mathematically in bilingual classsrooms: an exploratory study of teacher discourse. *Proceedings of the 14th Conference for the International Group for the Psychology of Mathematics Education*, Mexico, July 15-20, *3*, pp. 105–111. Mexico.

Khisty, L.L. & Chval, K. (2002). Pedagogical discourses and equity in mathematics: when teachers' talk matters. *Mathematics Education Reserarch Journal,* 14(3): 154–168.

Kothari, C. (2009). *Research methodology: methods and techniques*. New Delhi: New Age International.

Lambert, W.E. (1981). Bilingualism and language acquisition. *Annals of the New York Academy of Science*: 9–22.

Lapadat, J. (2000). Problematizing transcription: purpose, paradigm and quality. *International Journal of Social Research Methodology*, vol. 3, 203–219.

Lapadat, J. & Lindsay, A. (1999). Transcription in research and practice: from standardization of techniques to interpretive positioning. *Qualitative Inquiry,* 5: 64–86.

Llabre, M. & Cuevas, G. (1983). The effects of test language and mathematical skills assesed on the scores of bilingual Hispanic students. *Journal for Research in Mathematics Education,* 14(5): 318–324.

Macnamara, J. (1967). The effects of instruction in a weaker language. *Journal of Social Issues*, *XXIII*(2): 121–135.

Mazrui, A. & Mazrui, A.M. (1995). *Swahili state and society: the political econony of an African language.* Nairobi, London: East African Educational Publishers.

Mbaabu, I. (1985). *New horizons in Kiswahili: a synthesis in developments, research and literature.* Nairobi: Kenya Literature Bureau.

Mbaabu, I. (1996). *Language policy in East Africa.* Nairobi: East African Educational Publishers.

Mercer, N. (1995). *The guided construction of knowledge: talk amongst teacahers and learners.* Clevedon: Multilingual Matters.

Merriam, S.B. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass.

Merrit, M., Cleghorn, A., Abagi, J. & Bunyi, G. (1992). Socialising multilinguailism: determinants of code-switching in Kenyan primary classrooms. *Journal of Multilingual and Multicultural Dvelopment*, 13(1/2): 103–121.

Mestre, J.P. (1981). Predicting academic achievement among bilingual Hispanic college technicalstudents. *Educational and Psychological Measurement*, vol. 41: 1255–1264.

Mestre, J.P. (1988). In R.R. Cocking, & J.P. Mestre, *Linguistic and cultural inflluences on learning mathematics*. Hillsdale, N.J: L Erlbaum Associates.

Minichiello, V., Aroni, R., Timewell, E. & Alexander, L. (1990). *In-depth interviewing: researching people.* Longman Cheshire: Longman Cheshire.

Mishler, E.G. (1990). Validation in inquiry-guided research: the role of exmplars in narrative studies. *Harvard Educational Review,* 60(1): 415–441.

Moschkovich, J. (1996). Learning math in two languages, in Puig, L. & Gutierrez, A (Eds). *Proceedings of the 20th Conference of the International Group for the Psychology of Mathematics Education*, July 8-12, *4* , pp. 27–34, Valencia: Spain.

Moschkovich, J. (1999). Supporting the participation of English language learners in mathematical discussions. *For Learning Mathematics*, 19(1): 11–19.

Moschkovich, J. (2002). A situated and sociocultural perspective on bilingual mathematics learners. *Mathematical Thinking and Learning*, vol. 4: 189–212.

Moschkovich, J. (2003). What counts as mathematics discourse? *Proceedings of the 27th Conference for the International Group for the Psychology of Mathematics Education*, vol. 3, pp. 325–332.

Moschkovich, J. (2005). Using two languages when learning mathematics. *Educational Studies in Mathematics,* 64: 121–144.

Mugenda, O. & Mugenda, A.G. (2003). *Research methods: qualitative and quantitative approaches.* Nairobi: ACTS.

Nabea, W. (2009). Language policy in Kenya: negotiation with hegemony. *The Journal of Pan African Studies*, 3(1): 121–138.

Ndayipfukamiye, L. (1994). Code-switching in Burundi primary schools, in C.M. Rubagumya, *Teaching and researching language in African classrooms*, Clevedon, Avon: Multilingual Matters, pp. 79–95.

Newman, M. (1977). An analysis of sixth-grade pupils' errors on written mathematical tasks. *Victorian Institute for Educational Research Bulletin* 39, pp 31–43.

Ni Riordain, M. & O'Donoghue, J. (2009). The relationship between performances on mathematical word problems and language profiency for students learning through the medium of Irish. *Educational Studies in Mathematics*, vol. 71: 43–64.

Ni Riordain, M. & O'Donoghue, J. (2011). Trackling the transition – the English mathematics register and students learning through the medium of Irish. *Mathematics Educational Research Journal, DOI 10.1007/s13394-011-0003-6* published online 7th June .

Nkambule, T., Setati, M. & Duma, B. (2010). One mathematics classroom, multiple languages in Pinto, M.F and Kawasaki, T.F. (Eds). *Proceedings of the 34th Conference for International Group of Psychology of Mathematics Education*, Belo Horizonte, Brazil: PME, pp. 345–352.

Ogechi, N. (2002). *Trilingual codeswitching in Kenya – Evidence from Ekegusii, Kiswahili, English and Sheng.* Hamburg: Unpublished doctoral dissertation, University of Hamburg.

Ogechi, N. O. (2009). The Role of Foreign and Indigenous Languages in Primary Schools: The Case of Kenya. *Stellenbosch Papers in Linguistics Plus, 38*, 143-158.

Opie, C.E. (2004). *Doing educational research.* London: Sage.

Orton, A. (1992). *Learning mathematics issues.* London: The Falmer Press.

Parvanehnezhad, Z. & Clarkson, P. (2008). Iranian bilingual students' reported use of language switching when doing mathematics. *Mathematics Education Research Journal*, 20(1): 51–81.

Patton, M.Q. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, CA: Sage.

Phakeng, M.S. (2013). Mathematics education and language diversity: past, present and future. *Fourth Africa Regional Congress of International Commission on Mathematical Instruction* Maseru, Lesotho, , pp. 14–24..

Pimm, D. (1981). Mathematics? I speak it fluently. In A. Floyd, *Developing mathematical thinking* (pp. 139-150). Wokingham: Addison Wesley.

Pimm, D. (1987). *Speaking mathematically: communication in mathematics classrooms*. London and New York: Routledge & Kegan Paul.

Pimm, D. (1991). Communicating mathematically, in Durkin, K. & B. Shire (Eds). *Language in mathematics education,* Milton Keynes: Open University Press, pp. 17–23.

Planas, N. (2011). Language identities in students' writings about group work in their mathematics classroom. *Language and Education*, 25(2): 129–-146.

Planas, N. & Civil, M. (2010). Mathematical thinking and language switching as seen by Latin American students in Barcelona, in Pinto, M.F. & T.F. Kawasaki (Eds), *Proceedings of 34th Conference of the International Group for the Psychology of Mathematics Education, 4*, pp. 49–56. Belo Horizonte, Brazil: PME.

Planas, N. & Civil, M. (2008). Voices of non-immigrant students in the multi-ethnic mathematics classroom. *Proceedings of the Conference of the International Group for the Psychology of Mathematics Education, 4*, pp. 121–127.

Planas, N. & Setati, M. (2009). Bilingual students using their languages in the learning of mathematics. *Mathematics Education Research Journal*, 2(3): 36–59.

Republic of Kenya (RoK). (2010). *Constitution of Kenya.* Nairobi: Government Press.

Rowland, T. (1999). Pronouns in mathematics talk: power, vagueness and generalizations. *For the Learning of Mathematics*, 19(2): 19–26.

Saer, D.J. (1923). The effect of bilingualism on intelligence. *Bristish Joiurnal of Psychology,* vol. 14: 25–38.

Setati, M. (1998). Code-switching in a senior primary class of second-language mathematics learners. *For Learning Mathematics*, vol. 18: 34–40.

Setati, M. (2002). *Language practices in multilingual classrooms in South Africa*. Unpublished Doctoral Dissertation, University of Witwatersrand, Johannesburg, South Africa.

Setati, M. (2003). 'Re'-presenting qualitative data from multilingual mathematics classrooms. *ZDM*, 35(6): 294–300.

Setati, M. (2005). Teaching mathenatics in a primary multilingual classroom. *Journal for Research in Mathematics Education*, 36(5): 447–466.

Setati, M. (2008). Access to mathematics versus access to the language of power: the struggle in multilingual mathematics classrooms . *South African Journal of Education*, vol. 28: 103–116.

Setati, M. & Adler, J. (2000). Between languages and discourses: language practices in primary multilingual mathematics classrooms in South Africa. *Educational Studies in Mathematics,* vol. 43: 243–269.

Setati, M., Adler, J., Reed, Y. & Bapoo, A. (2002). Incomplete journeys: code-switching and other language practices in mathematics, science and English language classrooms in South Africa. *Language and Education,* vol. 16: 128–149.

Setati, M., Chitera, N. & Essien, A. (2009). Research on multilingualism in mathematics education in South Africa: 2000–2007. *African Journal of Research in Mathematics Science and Technology Education*, 13(Special issue): 65–80.

Setati, M. & Duma, B. (2009). When language is transparent: supporting mathematics learning in multilingual contexts, in Tzekaki, M., Kaldrimidou, M. & Sakonidis,

H. (Eds). *Proceedings of the 33rd Conference for the International Group for the Psychology of Mathematics Education*, Thessalonikki, Greece, pp. 65–72.

Setati, M., Molefe, T. & Langa, M. (2008). Using language as a transparent resource in the teaching and learning of mathematics in a Grade 11 multilingual classroom. *Pythagoras,* 67: 14–25.

Setati, M. & Planas, N. (2012). Mathematics education across two language contexts: a political perspective, in Skovsmose, O. & Greer, B. (Eds), *Opening the Cage: Critique and Politics of Mathematics Education,* Sense Publishers, pp. 167–186.

Sfard, A., Nesher, P., Sreefland, L., Cobb, P. & Mason, J. (1998). Learning mathematics through conversations: is it as good as they say? *For the Learnong of Mathematics,* 18(1): 41–51.

Shiundu, J. S. & Omulando, S.J. (1992). *Curriculum: theory and practice in Kenya.* Nairobi: Oxford University Press.

Stacey, K. & MacGregor, M. (1991). Difficulties of students with limited English language skills in pre-service mathematics education courses. *Mathematics Educational Research Journal,* 3(2): 14–23.

Swain, M. & Cummins, J. (1979). Bilingualism, cognitive functioning and education. *Language Teaching*, 12(1): 4–18.

Thompson, P.W., & Thompson, A.G. (1994). Talking about rates conceptually, Part I: a teacher's struggle. *Journal for Research in Mathematics Education,* 25(3): 279–303.

Tilley, S.A. (2003). "Challenging" research practices: turning a crical lens on the work of transcription. *Qualitative Inquiry*, 9(5): 750–773.

Tilley, S.A., & Powick, K.D. (2002). Distanced data: transcribing others people's research tapes. *Canadian Journal of Education,* 27(2 & 3): 291–310.

UNESCO. (1974). *The interactions between linguistics and mathematical education*. Nairobi: UNESCO, CEDO & ICMI.

University World News. (22/9/2010). *Entry points lowered to boost access.* London. Available online: www.universityworldnews.com [Accessed 22/9/2010]

Vygotsky, L.S. (1986). *Thought and language.* Cambridge, Mass: MIT Press.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L.S. (1991). Genesis of higher mental functions, in Light, P., Sheldon, S. & Woodhead, M. (Eds), *Learning to think.* London: Routledge in association with Open University Press.

Yin, R.K. (1989). *Case study research: design and methods*. Newbury Park CA: Sage.

Yin, R.K. (2003). *Applications of case study research.* Thousand Oaks: Sage.

Zepp, R.A. (1982). Bilinguals understanding logical connectives in English and Sesotho. *Educational Studies in Mathematics,* vol. 13: 205–221.

APPENDIX A: ETHICAL CLEARANCE LETTER

UNISA college of science, engineering and technology

Ms E W Njurai (47299878) 2011-05-13
School of Computing (Student), UNISA
Pretoria

Permission to conduct PhD (Mathematics education) research project

Ref: 015/EWN/2011

The request for ethical approval for your PhD (Mathematics Education) research project entitled "An investigation into how undergraduate students' competence in the language of teaching and learning (LoLT) shapes their engagement with mathematics tasks"[40] refers.

The College of Science, Engineering and Technology's (CSET) Research and Ethics Committee (CREC) has considered the relevant parts of the studies relating to the above mentioned research project and research methodology and is pleased to inform you that ethical clearance is granted for your study as set out in your proposal and application for ethical clearance.

Therefore, involved parties may also consider ethics approval as granted. However, the permission granted must not be misconstrued as constituting an instruction from the CSET Executive or the CSET CREC that sampled interviewees (if applicable) are compelled to take part in the research project. All interviewees retain their individual right to decide whether to participate or not.

We trust that there search will be undertaken in a manner that is respectful of the rights and integrity of those who volunteer to participate, as stipulated in the UNISA Research Ethics policy. The policy can be found at the following URL:
http://cm.unisa.ac.za/contents/departments/res_policies/docs/ResearchEthicsPolicy_apprvCounc_21Sept07.pdf

Please note that if you subsequently do a follow-up study that requires the use of a different research instrument, you will have to submit an addendum to this application, explaining the purpose of the follow- up study and attach the new instrument along with a comprehensive information document and consent form.

Yours sincerely

H H Lotriet

Prof HH Lotriet
Acting Chair: School of Computing Ethics Sub-Committee

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[40] The title of the thesis has since changed to "Language Practices of Trilingual Undergraduate Students Engaging with Mathematics in Kenya". This change was necessitated by the need to narrow on the scope to the language practices of trilingual undergraduate students.

APPENDIX B: INVITATION AND CONSENT LETTER

Evelyn W. Njurai

Cellphone; +25472 2251363 or +2772 399 2090

Email: evelynnjurai@yahoo.com or njuraew@unisa.ac.za

29 April 2011

The Principal

Procity University, Kenya

Dear Sir,

REF: PERMISSION TO COLLECT DATA FOR MATHEMATICS EDUCATION RESEARCH

My name is Evelyn W. Njurai. I am a student at the University of South Africa, currently undertaking a PhD in Mathematics Education. As part of the degree requirement, I need to carry out research. My research is entitled **"An investigation into how undergraduate students' competence in the language of teaching and learning (LoLT) shapes their engagement with mathematics tasks".**

I am writing to request your permission to conduct research with some undergraduate students enrolled in mathematics courses. In particular, I will explore why students use language(s) as they do when engaging with a given mathematics task.

In order to obtain the relevant information in this study, I will adopt a qualitative case study approach. The target group will be first-year multilingual students who scored better grades in mathematics than in English in KCSE. I will select a total of 15 students from three programmes. I will then collect data using students' questionnaire as well as clinical and reflective interviews.

Due to anticipated use of different languages by the students, a language translator knowledgeable in mathematics will be present during the interviews. For accurate data collection, I will video and audio tape the interview proceedings. The plan is to collect the data in the period May-August 2011.

The data so collected and the identity of the students will be treated with confidentiality. The identities of the students will be concealed, in any presentation and publication emerging from this research, by use of pseudonyms. The link to their real names will only be accessed by the researcher and the supervisor. If, however, for any reason they would like their real names to be used in any future presentation, they will need to make written request to me, as the researcher. There are no known or anticipated risks to the students who will participate in this study.

Once the research has been completed, a brief summary of the findings will be available to the students on request. The findings of the study will also be presented in academic conferences and published in national and international academic journals.

The participation of your university in this research project is completely voluntary. Should the university wish to withdraw at any stage, or withdraw any unprocessed data that will have been supplied, it will be free to do so without prejudice. The decision to participate or not, or to withdraw, will be completely independent of your university dealings with the University of South Africa.

I therefore request your permission to conduct the research on the selected students. I have enclosed a copy of informed consent and students' invitation to the research. Should you have any questions or concerns regarding this letter or my research, please contact me at the address given. You may also contact my supervisor Prof M. Setati on email Setatrm@unisa.ac.za.

Sincerely

Evelyn W. Njurai

PhD Candidate.

Consent form for the Principal

UNIVERSITY OF SOUTH AFRICA

MATHEMATICS LANGUAGE PROJECT

Researcher: Evelyn W. Njurai

Supervisor: Prof M. Setati

I .... agree that the university shall participate in the project named above, particulars of which (details of aim of research, procedure and students' obligations, research instruments and issues of confidentiality) have been explained to me. A written information letter has been given to me.

<u>I give consent to the following:</u>

- Video and/or tape recording of the interviews in which the students will appear as part of the videotext.

  Yes ☐ No ☐
- The presence of a language translator during the interviews.

  Yes ☐ No ☐
- The possible future use of the videotext for academic purposes

  Yes ☐ No ☐

....	....
Signature of the Vice Chancellor	Date
....	....
Signature of witness	Date
....	....
Signature of researcher	Date

Invitation letter to students

Evelyn W. Njurai
Cellphone; +27 72 399 2090
Email; evelynnjurai@yahoo.com or njuraew@unisa.ac.za

Dear Student

My name is Evelyn W. Njurai. I 'am a student at the University of South Africa, currently undertaking a PhD in Mathematics Education. Your contact details have been provided to me by the Head of your School in order to receive this invitation for possible participation in my research.

In an attempt to understand how language of learning and teaching competence shapes students' engagement with mathematics tasks, I will explore how multilingual first year students' competence in the language of learning and teaching shapes their engagement with mathematics tasks. In particular I will explore why students use language(s) as they do when engaging with a given mathematics task and other strategies that they employ in order to succeed in mathematics.

If you agree to participate in the study, you will be requested to complete a questionnaire on your personal data. From the questionnaire responses, I will select 15 students who will eventually engage with two 30 minutes interviews. For effective and accurate data recording, video/audio recording alongside field notes as the interviews proceed will be done. This will be done in the period May- August 2011.

If you choose to participate, it will be on voluntarily bases and no incentives will be offered. Declining to participate at any stage of the study, shall not attract any penalty. There are no known or anticipated risks to you as a participant in this study.

The data collected shall be treated with confidentiality. This will be achieved by use of pseudonyms, which will conceal your identity. If, however, for any reason you would like your real name to be used in any future presentation, you will need to make written request to me, as the researcher.

Once the research has been completed, a brief summary of the findings will be available to you on request. The findings will also be presented in academic conferences and published in national and international academic journals.

If you agree to be part of this research project please complete the consent form on the next page and sign in the space provided. For further information concerning the research, do not hesitate to contact me on the cell phone numbers or email address given.

Sincerely

Evelyn W. Njurai

Consent form for students

UNIVERSITY OF SOUTH AFRICA

MATHEMATICS LANGUAGE PROJECT

Researcher: Evelyn W. Njurai

Supervisor: Prof M. Setati

I.. agree to participate in th project named above, particulars of which (i.e. details procedure, obligations and researc instruments and issues of confidentiality of data collected from me) have been explained to m A written information letter has been given to me.

I give consent to the following:

- Video recording of the interviews in which I might appear as part of the videotext.
  Yes ☐ No ☐
- The possible future use of the videotext for education purposes
  Yes ☐ No ☐

....	....
Signature of student	Date
....	....
Signature of witness	Date
....	....
Signature of researcher	Date

APPENDIX C: RESEARCH APPROVAL LETTER

Procity University, Kenya

Office of the Deputy Principal (academic Affairs)

May 11, 2011

Research Office
University of South Africa
P.O. Box 392
UNISA 0003
South Africa.

Dear Sir/Madam,

Re: Research by Evelyn Njurai

On behalf Procity University, Kenya, I am writing to formally indicate our awareness of the research entitled **"An investigation into how undergraduate students' competence in the language of teaching and learning (LoLT) shapes their engagement with mathematics tasks** proposed by Ms Evelyn W. Njurai, a PhD student at University of South Africa (UNISA). We are aware that Ms Evelyn W. Njurai intends to conduct her research by administering a written survey to our first year students and selecting fifteen students to be engaged in a 30-minute interview.
I am responsible for student's academic affairs and I give Ms Evelyn W. Njurai permission to conduct her research in our University.
If you have any questions or concerns, please feel free to contact my office.

Deputy Principal (AA)

APPENDIX D: QUESTIONNAIRE

Fill in the required details.

Gender.................... Age......................

1. Name of faculty...
2. Name of department...
3. Name of programme you are undertaking..
4. **Education Background**.
   Enter the grades you scored in KCSE in the table below.

Subject	**Grade**
English	
Mathematics	

5. **Language Background**.
   (i) What is your first language? ....
   (ii) Which language(s) do you use the most at home? (List them in the order from the one you use most to the one you use least).......................................
   ....
   (iii) Fill in the table below with at least two (2) languages, in order of use, you use most commonly when working things out mentally, when interacting with peers, and with mathematics lecturers, while engaging in mathematical tasks.

	Self	Peers	Lecturers
Class work	1. 2.	1. 2.	1. 2.
Assignments/ Project work	1. 2.	1. 2.	1. 2.
Examinations	1. 2.		

6. If you were given the chance to be interviewed about a mathematics task, which language would you use? ....

APPENDIX E: GRADES AND THE CORRESPONDING ABILITIES

Grades	**Abilities**
A, A-	Very Good
B+, B, B-	Good
C+, C, C-, D+	Average
D, D-	Weak
E	Poor

Source KNEC Website (2011)

APPENDIX F: JAB CLUSTER 2009/2010

JOINT ADMISSIONS BOARD - CLUSTERS FOR 2009/2010

CLUSTER	DEGREE PROGRAMMES	Cluster Groups of 4 Subjects 1	2	3	4
1.	BACHELOR OF LAW (LL.B)	ENG	MAT or any GROUP II	any Group III	KIS or a Group II Subj. or 2nd. Group III or any Group IV or any Group V
2.	BACHELOR OF ARTS (Comm. & Media Techn. With IT) BACHELOR OF CATERING & HOTEL MANAGEMENT BACHELOR OF EDUCATION (Library Science) BACHELOR OF HOTELS & HOSPITALITY MANAGEMENT BACHELOR OF LIBRARY & INFORMATION SCIENCE BACHELOR OF MASS COMMUNICATION BACHELOR OF SCIENCE (Communication & Media) BACHELOR OF SCIENCE (Ecotourism & Hospitality Management) BACHELOR OF SCIENCE (Ecotourism & Hospitality) BACHELOR OF SCIENCE (Ecotourism, Hotel & Inst. Mnag. With IT) BACHELOR OF SCIENCE (Hospitality & Tourism Management) BACHELOR OF SCIENCE (Information Science) BACHELOR OF SCIENCE (Media Science) BACHELOR OF TECHNOLOGY (Hotel and Restaurant Management) BACHELOR OF TECHNOLOGY (Tourism Management) BACHELOR OF TOURISM & TRAVEL MANAGEMENT BACHELOR OF TOURISM MANAGEMENT BACHELOR OF TRAVEL & TOURS OPERATIONS MNGMT.	ENG or KIS	MAT	any Group II or any Group III	a Group II Subj. or a Group III Subj. or any Group IV or any Group V
3.	BACHELOR OF ARTS BACHELOR OF ARTS (International Relations & Diplomacy) BACHELOR OF ARTS (Community Development) BACHELOR OF ARTS (Anthropology) BACHELOR OF ARTS (Communication & Media) BACHELOR OF ARTS (Cultural Studies) BACHELOR OF ARTS (Development Studies With IT) BACHELOR OF ARTS (Drama & Theatre Studies With IT) BACHELOR OF ARTS (Economics and Sociology) BACHELOR OF ARTS (English) BACHELOR OF ARTS (Gender & Development) BACHELOR OF ARTS (History and Economics) BACHELOR OF ARTS (History) BACHELOR OF ARTS (Int. Relations & Diplomacy With IT) BACHELOR OF ARTS (Linguistics) BACHELOR OF ARTS (Linguistics, Media and Communication) BACHELOR OF ARTS (Literature) BACHELOR OF ARTS (Penology, Correction & Administration) BACHELOR OF ARTS (Philosophy) BACHELOR OF ARTS (Political Science With IT) BACHELOR OF ARTS (Psychology) BACHELOR OF ARTS (Public Administration) BACHELOR OF ARTS (Religious Studies) BACHELOR OF ARTS (Social Work) BACHELOR OF ARTS (Sociology & Anthropology With IT) BACHELOR OF ARTS (Sociology and Religion) BACHELOR OF ARTS (Sociology) BACHELOR OF ARTS (Theatre Arts and Film Technology) BACHELOR OF ARTS (Theatre) BACHELOR OF ARTS (Theology) BACHELOR OF ARTS (Criminology & Security Studies) BACHELOR OF ARTS (With IT) BACHELOR OF ARTS EDUCATION (With IT) BACHELOR OF COMMUNICATION & PUBLIC RELATIONS BACHELOR OF CONFLICT RESOLUTION AND HUMANITARIAN ASSISTANCE BACHELOR OF CRIMINOLOGY BACHELOR OF EDUCATION (Arts) BACHELOR OF EDUCATION (Counselling Psychology) BACHELOR OF EDUCATION (Early Childhood & Primary Ed.) BACHELOR OF EDUCATION (Early Childhood Education) BACHELOR OF ENTREPRENEURSHIP & SMALL BUSINESS MGT. BACHELOR OF HEALTH SERVICES MANAGEMENT BACHELOR OF JOURNALISM & MASS COMMUNICATION BACHELOR OF PSYCHOLOGY BACHELOR OF SCIENCE (Communication & Public Relations) BACHELOR OF SCIENCE (Communication &Journalism) BACHELOR OF SCIENCE (Entrepreneurship Studies) BACHELOR OF SCIENCE (Graphic & Communication) BACHELOR OF SCIENCE (Health Records & Information Management) BACHELOR OF SCIENCE (Human Resource Management) BACHELOR OF SCIENCE (Population Health) BACHELOR OF SCIENCE (Project Planning & Management) BACHELOR OF SCIENCE (Strategic Management) BACHELOR OF SCIENCE(Counseling Psychology) BACHELOR OF SOCIAL WORK	ENG or KIS	MAT or any GROUP II	any GROUP III	2nd. Group III or any Group IV or any Group V

CLUSTER	DEGREE PROGRAMMES	Cluster Groups of 4 Subjects 1	2	3	4
4.	BACHELOR OF ARTS (Fine Art) BACHELOR OF EDUCATION (ARTS) FINE ART	ENG or KIS	MAT or any GROUP II	any GROUP III	a Group II Subj. or 2nd. Group III or any Group IV or any Group V
5.	BACHELOR OF EDUCATION (Guidance & Counselling) BACHELOR OF EDUCATION (Special Education) BACHELOR OF SPECIAL NEEDS EDUCATION (With IT)	ENG or KIS	BIO	any GROUP III	MAT or 2nd. Group II or 2nd. Group III or any Group IV or any Group V
6.	BACHELOR OF ARTS (Kiswahili)	KIS	ENG or MAT	any GROUP III	any Group II or 2nd. Group III or any Group IV or any Group V
7.	BACHELOR OF ACTURIAL SCIENCE BACHELOR OF ARTS (Business Studies with IT) BACHELOR OF ARTS (Economics with IT) BACHELOR OF ARTS (Economics) BACHELOR OF BUSINESS INFORMATION & MANAGEMENT BACHELOR OF BUSINESS ADMINISTRATION BACHELOR OF BUSINESS ADMINISTRATION (With IT) BACHELOR OF BUSINESS MANAGEMENT BACHELOR OF BUSINESS MANAGEMENT (Civil Aviation Management) BACHELOR OF BUSINESS MANAGEMENT (Marine Business Ma BACHELOR OF COMMERCE (B.COM.) BACHELOR OF ECONOMICS BACHELOR OF ECONOMICS & FINANCE BACHELOR OF ECONOMICS & STATISTICS BACHELOR OF PURCHASING & SUPPLIES MANAGEMENT BACHELOR OF SCIENCE (Applied statistics with Computing) BACHELOR OF SCIENCE (Actuarial Science With IT) BACHELOR OF SCIENCE (Actuarial Science) BACHELOR OF SCIENCE (Applied Statistics With IT) BACHELOR OF SCIENCE (Economics & Statistics) BACHELOR OF SCIENCE (Financial Engineering) BACHELOR OF SCIENCE (Statistics)	MAT	ENG or KIS	any GROUP III	any Group II 2nd. Group III or any Group IV or any Group V
8.	BACHELOR OF EARTH SCIENCE (With IT) BACHELOR OF SCIENCE (Geology) BACHELOR OF SCIENCE (Meteorology)	MAT	PHY	GEO	2nd. Group II or 2nd. Group III or any Group IV or any Group V

CLUSTER	DEGREE PROGRAMMES	Cluster Groups of 4 Subjects 1	2	3	4
	BACHELOR OF ENGINEERING (Aeronautical Engineering)	BACHELOR OF SCIENCE (Manufacturing Engineering&Technology)			
	BACHELOR OF ENGINEERING (Agriculture &Biosystems Eng.)	BACHELOR OF SCIENCE (Manufacturing Engineering)			
	BACHELOR OF ENGINEERING (Chemical & Process Engineering)	BACHELOR OF SCIENCE (Mechanical and Industrial Engineering)			
	BACHELOR OF ENGINEERING (Civil & Structural Engineering)	BACHELOR OF SCIENCE (Mechanical Engineering)			
	BACHELOR OF ENGINEERING (Civil Engineering)	BACHELOR OF SCIENCE (Mechatronic Engineering)			
	BACHELOR OF ENGINEERING (Computer Engineering)	BACHELOR OF SCIENCE (Mining and Mineral Processing Eng.)			
9.	BACHELOR OF ENGINEERING (Electrical & Electronic Eng.)	BACHELOR OF SCIENCE (Physics)			
	BACHELOR OF ENGINEERING (Electrical Apparatus & Systems)	BACHELOR OF SCIENCE (Soil,Water & Environmental Engineering)			
	BACHELOR OF ENGINEERING (Geospatial Engineering)	BACHELOR OF SCIENCE (Telecommunication & Infor. Tech.)			
	BACHELOR OF ENGINEERING (Manufacturing, Industrial & Textile Eng.)	BACHELOR OF SCIENCE (Telecommunication & Information Eng.)			
	BACHELOR OF ENGINEERING (Mechanical Engineering)	BACHELOR OF SCIENCE (Water & Environment Engineering)			
	BACHELOR OF ENGINEERING (Mechanical & Production Eng.)	BACHELOR OF SCIENCE (Water & Environment Engineering)			
	BACHELOR OF ENGINEERING (Telecommunication)	BACHELOR OF SCIENCE (Water Engineering)			
	BACHELOR OF SCIENCE (Agricultural Engineering)	BACHELOR OF SCIENCE(Electrical & Communications Eng.)			
	BACHELOR OF SCIENCE (Analytical Chemistry and Management)	BACHELOR OF TECHNOLOGY (Building and Civil Engineering)			
	BACHELOR OF SCIENCE (Analytical Chemistry)	BACHELOR OF TECHNOLOGY (Civil Engineering Tech.)			
	BACHELOR OF SCIENCE (Biomechanical & Processing Eng.)	BACHELOR OF TECHNOLOGY (Computer Technology)			
	BACHELOR OF SCIENCE (Chemistry)	BACHELOR OF TECHNOLOGY (Electrical & Electronic Eng. Tech.)			
	BACHELOR OF SCIENCE (Civil & Structural Engineering)	BACHELOR OF TECHNOLOGY (Electrical Power Engineering)			
	BACHELOR OF SCIENCE (Civil Engineering)	BACHELOR OF TECHNOLOGY (Electronic Engineering)			
	BACHELOR OF SCIENCE (Computer Engineering)	BACHELOR OF TECHNOLOGY (GeoInformation Tech.)			
	BACHELOR OF SCIENCE (Computer Science & Technology)	BACHELOR OF TECHNOLOGY (Geospatial Engineering Tech.)			
	BACHELOR OF SCIENCE (Computer Technology)	BACHELOR OF TECHNOLOGY (Information Technology)			
	BACHELOR OF SCIENCE (Control and Instrumentation)	BACHELOR OF TECHNOLOGY (Instrumentation & Control Engineering)			
	BACHELOR OF SCIENCE (Electrical & Electronic Engineering)	BACHELOR OF TECHNOLOGY (Land Surveying Tech.)			
	BACHELOR OF SCIENCE (Electronic & Computer Engineering)	BACHELOR OF TECHNOLOGY (Mechanical Engineering Tech.)			
	BACHELOR OF SCIENCE (Energy Engineering)	BACHELOR OF TECHNOLOGY (Mechanical Engineering)			
	BACHELOR OF SCIENCE (Environmental & Biosystems Eng.)	BACHELOR OF TECHNOLOGY (Telecommunication Engineering)			
	BACHELOR OF SCIENCE (Geomatic Eng. & Geospatial Information Systems)				
	BACHELOR OF SCIENCE (Geospatial Engineering)				
	BACHELOR OF SCIENCE (Industrial Chemistry and Management)				
	BACHELOR OF SCIENCE (Industrial Chemistry)				BIO
	BACHELOR OF SCIENCE (Information Technology)				or any Group III
	BACHELOR OF SCIENCE (Instrumentation & Control Engineering)	MAT	PHY	CHEM	or any Group IV
	BACHELOR OF SCIENCE (Land Surveying)				or any Group V
	BACHELOR OF ARCHITECTURAL STUDIES				2nd. Group II
	BACHELOR OF ARCHITECTURAL STUDIES /BACHELOR OF ARCHITECTURE	MAT	PHY	any Group III	or 2nd. Group III
10.	BACHELOR OF ARCHITECTURE				or any Group IV
	BACHELOR OF CONSTRUCTION MANAGEMENT				or any Group V
	BACHELOR OF LANDSCAPE ARCHITECTURE				
	BACHELOR OF QUANTITY SURVEYING				
	BACHELOR OF SCIENCE (Quantity Surveying)				
	BACHELOR OF TECHNOLOGY (Building Construction)				

CLUSTER	DEGREE PROGRAMMES	Cluster Groups of 4 Subjects 1	2	3	4
	BACHELOR OF APPLIED COMPUTER SCIENCE				
11.	BACHELOR OF BUSINESS and INFORMATION TECHNOLOGY				
	BACHELOR OF BUSINESS INFORMATION TECHNOLOGY				
	BACHELOR OF COMPUTER SCIENCE				
	BACHELOR OF SCIENCE (Applied Statistics with Computing)				
	BACHELOR OF SCIENCE (Computer Science)				
	BACHELOR OF SCIENCE (Mathematics and Computer Science)				a Group II Subj.
	BACHELOR OF SCIENCE (Mathematics)	MAT	PHY	2nd Group II	or a Group III Subj.
	BACHELOR OF SCIENCE (Software Engineering)			or any Group III	or any Group IV
	BACHELOR OF TECHNOLOGY (Business Information Technology)				or any Group V
	BACHELOR OF AGRIBUSINESS MANAGEMENT				3rd. Group II Subj.
12.	BACHELOR OF SCIENCE (Agribusiness Management and Trade)	MAT	BIO	PHY	or any Group III
	BACHELOR OF SCIENCE (Agribusiness Management)			or CHEM	or any Group IV
	BACHELOR OF SCIENCE (Agricultural Economics)				or any Group V
	BACHELOR OF SCIENCE(Agricultural Econ. & Resource Mngmt.)				
	BACHELOR OF EDUCATION (Science)				
	BACHELOR OF EDUCATION (Technology)				3rd. Group II Subj.
	BACHELOR OF SCIENCE (B.Sc.)	MAT	any Group II	2nd Group II	or any Group III
13.	BACHELOR OF SCIENCE (Primary Education)				or any Group IV
	BACHELOR OF SCIENCE (With IT)				or any Group V
	BACHELOR OF SCIENCE EDUCATION (With IT)				
	BACHELOR OF ARTS (Design)				2nd. Group II
	BACHELOR OF ARTS (Land Economics)	MAT	any Group II	any Group III	or 2nd. Group III
14.	BACHELOR OF ARTS (Planning)				or any Group IV
	BACHELOR OF ARTS (Urban & Regional Planning With IT)				or any Group V
	BACHELOR OF SCIENCE (Urban Design and Development)				
	BACHELOR OF SCIENCE (Land Administration)				
	BACHELOR OF TECHNOLOGY (Design)				
15.	BACHELOR OF ARTS (Interior Design With IT)				ENG
	BACHELOR OF ARTS (Textile, Apparel Design & Fashion, Merchandising With IT)	CHEM	PHY	BIO	or KIS
	BACHELOR OF SCIENCE (Apparel and Fashion Technology)		or MAT	or HSC	or any Group III
	BACHELOR OF SCIENCE (Clothing, Textiles & Interior Design)				or a Group IV Subj.
	BACHELOR OF SCIENCE (Fashion Design & Marketing)				or any Group V
					ENG
16.	BACHELOR OF SCIENCE (Recreation & Leisure Management)	BIO	MAT	PHY	or KIS
				or CHEM	or any Group III
					or any Group IV
					or any Group V
17.	BACHELOR OF EDUCATION (Physical Education & Sports)	BIO	PHY	MAT	CHEM
	BACHELOR OF SCIENCE (Exercise & Sport Science)				or any Group III
					or any Group IV
					or any Group V
	BACHELOR OF DENTAL SURGERY (B.D.S.)				ENG
18.	BACHELOR OF MEDICINE & BACHELOR OF SURGERY(M.B.Ch.B.)				or KIS
	BACHELOR OF PHARMACY				or a 3rd. Group II Subj.
	BACHELOR OF SCIENCE (Environmental Health)			MAT	or any Group III
	BACHELOR OF SCIENCE (Nursing &Public Health)	BIO	CHEM	or PHY	or any Group IV
	BACHELOR OF SCIENCE (Nursing)				or any Group V

CLUSTER	DEGREE PROGRAMMES	Cluster Groups of 4 Subjects 1	2	3	4
19.	BACHELOR OF SCIENCE (Biochemistry) BACHELOR OF SCIENCE (Biology) BACHELOR OF SCIENCE (Biomedical Technology) BACHELOR OF SCIENCE (Biomedical Sci.& Techn. With IT) BACHELOR OF SCIENCE (Biomedical Science & Technology) BACHELOR OF SCIENCE (Biotechnology) BACHELOR OF SCIENCE (Conservation Biology) BACHELOR OF SCIENCE (Forensic Science) BACHELOR OF SCIENCE (Medical Laboratory Science) BACHELOR OF SCIENCE (Microbiology & Biotechnology) BACHELOR OF SCIENCE (Microbiology) BACHELOR OF SCIENCE (Molecular & Cell Biology) BACHELOR OF TECHNOLOGY (Biotechnology) BACHELOR OF TECHNOLOGY (Industrial Microbiology & Biotechnology) BACHELOR OF TECHNOLOGY (Medicine Laboratory Tech.) BACHELOR OF TECHNOLOGY (Science Laboratory Technology) BACHELOR OF VETERINARY MEDICINE	BIO	CHEM	MAT or PHY	a 3rd. Group II Subj. or any Group III or any Group IV or any Group V
20	BACHELOR OF ENVIRONMENTAL SCIENCE (With IT) BACHELOR OF ENVIRONMENTAL STUDIES (Environ. Res. Cons.) BACHELOR OF ENVIRONMENTAL STUDIES (Science) BACHELOR OF ENVIRONMENTAL STUDIES (Science) BACHELOR OF SCIENCE (Agricultural Bio-systems & Management) BACHELOR OF SCIENCE (Agricultural Biotechnology) BACHELOR OF SCIENCE (Agricultural Education & Extension) BACHELOR OF SCIENCE (Agricultural Education) BACHELOR OF SCIENCE (Agricultural Resources Management) BACHELOR OF SCIENCE (Agriculture & Human Ecology Extension) BACHELOR OF SCIENCE (Agriculture) BACHELOR OF SCIENCE (Agroforestry & Rural Development) BACHELOR OF SCIENCE (Animal Health) BACHELOR OF SCIENCE (Animal Health, Production & Processing) BACHELOR OF SCIENCE (Animal Production & Health Management) BACHELOR OF SCIENCE (Animal Production) BACHELOR OF SCIENCE (Animal Science) BACHELOR OF SCIENCE (Applied Aquatic Science) BACHELOR OF SCIENCE (Bio-Resources, Conservation & Management.) BACHELOR OF SCIENCE (Coastal and Marine Resource Management) BACHELOR OF SCIENCE (Community Development) BACHELOR OF SCIENCE (Crop Production) BACHELOR OF SCIENCE (Crop Protection & Improvement) BACHELOR OF SCIENCE (Dairy Technology & Management) BACHELOR OF SCIENCE (Disaster Mitigation &Sustainable Dev.) BACHELOR OF SCIENCE (Disaster Preparedness & Env. Tech.) BACHELOR OF SCIENCE (Dry land, Agriculture & Enterprises Dev.) BACHELOR OF SCIENCE (Env. Conserv & Natural Resourses) BACHELOR OF SCIENCE (Environmental Education) BACHELOR OF SCIENCE (Environmental Horticulture & Landscaping Technology) BACHELOR OF SCIENCE (Environmental Science) BACHELOR OF SCIENCE (Fisheries & Aquatic Science) BACHELOR OF SCIENCE (Food Nutrition & Dietetics) BACHELOR OF SCIENCE (Food Science & Nutrition) BACHELOR OF SCIENCE (Food Science & Postharvest Tech.) BACHELOR OF SCIENCE (Food Science & Technology) BACHELOR OF SCIENCE (Food Service Technology) BACHELOR OF SCIENCE (Forestry) BACHELOR OF SCIENCE (Horticultural Science & Management) BACHELOR OF SCIENCE (Horticulture With IT) BACHELOR OF SCIENCE (Horticulture) BACHELOR OF SCIENCE (Land Resource Planning & Management) BACHELOR OF SCIENCE (Management of Agro-ecosys. & Env.) BACHELOR OF SCIENCE (Natural Resources) BACHELOR OF SCIENCE (Nutrition & Dietetics with IT) BACHELOR OF SCIENCE (Range Management) BACHELOR OF SCIENCE (Seed Science & Technology) BACHELOR OF SCIENCE (Soils and Land Use Management) BACHELOR OF SCIENCE (Sugar Technology) BACHELOR OF SCIENCE (Wildlife Management) BACHELOR OF SCIENCE (Wildlife Enterprise & Management) BACHELOR OF SCIENCE (Wood Science & Industrial Processes) BACHELOR OF SCIENCE (Wood Science & Technology) BACHELOR OF TECHNOLOGY (Nutrition and Dietetics)	BIO	CHEM	MAT or PHY or GEO	ENG or KIS or 3rd. Group II Subj. or a Group III Subj. or any Group IV or any Group V
21.	BACHELOR OF ARTS (Geography) BACHELOR OF ENVIRONMENTAL PLANNING & MANAGEMENT BACHELOR OF ENVIRONMENTAL STUDIES (Arts) BACHELOR OF ENVIRONMENTAL STUDIES (Community Dev.) BACHELOR OF SCIENCE (Disaster Mngmnt. & Int. Diplomacy) BACHELOR OF SCIENCE (Geography)	GEO	MAT	any GROUP II	2nd. Group II or 2nd. Group III or any Group IV or any Group V
22.	BACHELOR OF ARTS (History)	HAG	ENG or KIS	MAT or any GROUP II	a Group II Subj. or 2nd. Group III or any Group IV or any Group V
23.	BACHELOR OF EDUCATION ARTS (Home Economics) BACHELOR OF SCIENCE (Community Resource Management)	any GROUP II	ENG or KIS or MAT	any Group III	2nd. Group II or 2nd. Group III or any Group IV or any Group V

CLUSTER	DEGREE PROGRAMMES	1	2	3	4
					Cluster Groups of 4 Subjects
24.	BACHELOR OF ARTS (French) BACHELOR OF EDUCATION (ARTS) FRENCH BACHELOR OF EDUCATION (French)	FRE	ENG or KIS or MAT	any Group III	any Group II or 2nd. Group III or any Group IV or 2nd. Group V
25.	BACHELOR OF ARTS (German) BACHELOR OF EDUCATION (ARTS) GERMAN	GER	ENG or KIS or MAT	any Group III	any Group II or 2nd. Group III or any Group IV or 2nd. Group V
26.	BACHELOR OF ARTS (Music With IT) BACHELOR OF ARTS (Music) BACHELOR OF EDUCATION (ARTS) MUSIC BACHELOR OF MUSIC	MUS	ENG or KIS or MAT	any Group III	any Group II or 2nd. Group III or any Group IV or 2nd. Group V
27	BACHELOR OF SCIENCE (Astronomy & Astrophysics) BACHELOR OF SCIENCE (Microprocessor Technology & Instrumentation	MAT	PHY	CHEM or BIO	any Group III or any Group IV or any Group V

K.C.S.E. SUBJECT GROUPING

	abb.	Subject			SUBJECT SELECTION	
GROUP I	ENG KIS MAT	ENGLISH KISWAHILI MATHEMATICS			COMPULSORY COMPULSORY COMPULSORY	(3)
GROUP II	BIO PHY CHE	BIOLOGY PHYSICS CHEMISTRY			AT LEAST TWO	(2)
GROUP III	HAG GEG CRE IRE HRE	HISTORY AND GOVERNMENT GEOGRAPHY CHRISTIAN RELIGIOUS EDUCATION ISLAMIC RELIGIOUS EDUCATION HINDU RELIGIOUS EDUCATION			AT LEAST ONE	(1)
GROUP IV	HSC ARD AGR WDW MTW BCN	HOME SCIENCE ART AND DESIGN AGRICULTURE WOODWORK METALWORK BUILDING CONSTRUCTION	PME ELE DWD AVT CMP	POWER MECHANICS ELECTRICITY DRAWING AND DESIGN AVIATION TECHNOLOGY COMPUTER STUDIES		
GROUP V	FRE GER ARB	FRENCH GERMAN ARABIC	MUS BST	MUSIC BUSINESS STUDIES		

Selection of the SEVENTH SUBJECT:

Candidates select the 7th Subject from the remaining subjects in GROUPS II, III, IV or V

APPENDIX G: CLINICAL INTERVIEW QUESTION:

Topic; Algebra

1. A hall can accommodate 600 chairs arranged in rows. Each row has the same number of chairs. The chairs are rearranged such that the number of rows is increased by 5 but the number of chairs per row is decreased by 6.
    a) Find the original number of rows of chairs in the hall.
    b) After the rearrangement, 450 people were seated in the hall leaving the same number of empty chairs in each row. Calculate the number of empty chairs per row.

APPENDIX H: SUMMARY OF STUDENTS' LANGUAGE BACKGROUND

STUDENTS' CODE.	**DEGREE PROGRAMME: BACHELOR OF SCIENCE IN**	**Home language**
S1	Geomatic Engineering & Geospatial Information Systems	Kikuyu
S2	Geomatic Engineering & Geospatial Information Systems	Kikuyu
S3	Geomatic Engineering & Geospatial Information Systems	Luluhya
S4	Geomatic Engineering & Geospatial Information Systems	Dholuo
S5	Geomatic Engineering & Geospatial Information Systems	Kikuyu
S6	Mechatronics Engineering	Kiswahili
S7	Mechatronics Engineering	Kikuyu
S8	Mechatronics Engineering	Kiswahili
S9	Mechatronics Engineering	Dholuo
S10	Civil Engineering	Kikamba
S11	Civil Engineering	Ekegusi
S12	Civil Engineering	Luluhya
S13	Civil Engineering	Kikuyu
S14	Civil Engineering	Dholuo
S15	Civil Engineering	Kikuyu

APPENDIX I: SAMPLE TRANSCRIPTS

Clinical Interview Transcript for PS4

The student was asked to read the question and, when ready to start, he explained and justified the process. He read the question silently and then read aloud.

R: With that reading are you ready to start doing it? {he nods}….So I request that you will explain as you proceed.

PS4: Ok {he reads the first sentence again} When chairs are arranged in rows, {sketching horizontal lines and an outer rectangular frame}, that is our hall. The chairs are arranged in rows {pointing to the horizontal lines, then continues reading the question and subdivides the first horizontal line into parts}, they have the same number of chairs, let's call it ***n*** {writes ***n*** at the end}.

The chairs are rearranged.... {continues to read third sentence}. So let's say initially there was a number ***x*,** there were ***x*** rows, and each row, each row had 600/***x*** chairs.

Then after the rearrangement, the number of rows increased by 5, therefore (***x***+5) rows. So each row, had how many chairs? Had 600/(***x***+5*)*, because the number we are told it can accommodate 600, the number remains the same *(x+5)*. These {600(/***x***+5} are the new number per every row... but the chair, the number of chairs per row, decrease decreased by …. 5.

R: By?

PS4: Ooh, by 6. So this was, now we are relating this to this (600/***x*** and 600/***x***+5). The relationship of 600/***x*** = 600/***x***+5, let me do that {equating but indicating that they are not equal as he tries to find the relationship}. I need to know the relationship that will equate this two and we are given that relationship as this the number of chairs per row is decreased by six. So this one {the left hand side of the equation} is less 6 chairs so if we add this to 6 it gives us this right {right hand side}.Therefore, right, we can go to (a) after interpreting the whole question we know the rows are ***x*,** 600/***x***=600/(***x***+5) + 6. Then we can multiply by ***x*** to the all numbers... {works to obtain 600 +3000=600***x***+6***x***+30}.

R: You multiplied by ***x*** everywhere? (Referring to the step where he had not multiplied one term by ***x*.**)

PS4: Ooh, no there was also $6\boldsymbol{x}$ here {corrected to obtain $600\boldsymbol{x}+3000=600\boldsymbol{x}+6\boldsymbol{x}^2+30$}. So if you take this {referring to the left hand side of the equation} to this side {to the right side} you get … get $0=6\boldsymbol{x}^2-2070$. So $6\boldsymbol{x}^2=2070$, $\boldsymbol{x}^2$… {R interjects}.

R: Where did the $600\boldsymbol{x}$ go? Okay, it has gone with that.

PS4: This has cancelled {$600\boldsymbol{x}$ on both sides}. Then we remained with $3{,}000=6\boldsymbol{x}^2+30$. Then $0=6\boldsymbol{x}^2-2070$, then I can divide to get $\boldsymbol{x}^2=245$. So $\boldsymbol{x}=\sqrt{245}$…$\boldsymbol{x}=$ to…{R noting the need for a calculator in order to get the square root asked}.

R: Do you have your phone with you?

PS4: I have my phone but I don't think it has square root {works using brackets}; $\boldsymbol{x}$ gives us a decimal, 15.6, ok; even if it gives us a decimal it's ok. We are told, it can accommodate a maximum of 600 so we have to ignore this {decimal} so we can't round off. Because if we round off the extra chair will have no space so we retain 15 chairs in a row assuming that we have not gone anywhere wrong.

R: Ok, now you have made that assumption do you want to go back...backwards and check your answer? …3000 less 30, you got this 2070.

PS4: Ooh, oh, yeah that was the problem, yeah {repeats and obtains 2970}. We have 2970/6=495 we will work with 495. So $\boldsymbol{x}^2=495$, then $\boldsymbol{x} = \sqrt{495}=22.25$… . So I will just say what I said is, it gives us 22 chairs. Then, okay we can prove, we say if…if each row had 22 chairs, yeah... we can find how many rows were there, right? ...we divide 600/22 it will give us …27. It will give us 27 rows. Then you are told that the number of rows were increased by 5. If this {27} were increased by 5 then they are 32. Let us see how many chairs will…so we divide 600/32.We get 18, and we are told the number of chairs per row changed by 5. Here we have a 6.

R: So the original $\boldsymbol{x}$ is {number of rows}?

PS4: Is $\boldsymbol{x}$ which is 22, yeah ... and after proving … my answer is wrong

R: Why do you think it is wrong?

PS4: Because they say the numbers of chairs here increase by 5 …

R: So if they increased they are the ones you have given as 32...

PS4: Yeah, and now we are supposed to find chairs….the chairs.

R: So it was 600/32.

PS4: About 18. Yeah, so you get that, in each row were 18. You see each row were this {18.75} and we got it 18. And each row should give us (***x***+5) and the (***x***+5) should be ... plus 5 and it will only give us this number if we add it to 6.

R: and there we are... 27 to 32 these are rows,

PS4: Okay here is what I have done. These are the number of rows they are supposed to increase to this {32} right? Then I am proving it. Here you are told these are the number of rows after it changes, but each row has this number of chairs, right? And if after dividing this {600/32}, we are finding it's 18 chairs per row, this is the new this is the old {referring to ***x*** and (***x***+5)} isn't it?

R: Yeah

PS4: And it should change by 5 and yet is changing by 6.

R: So what would you say?

PS4: I will continue with the question with this (5) but I will put a mark to the question and then I confirm later.

R: Ok

PS4: Yeah because if it was an examination, I would check time first then I calculate how I understand the question then after getting the answer, then I approach the teacher. Either there is a problem with the question or I have not quite understood the question.

R: So you want to go to part (b) now with those answers?

PS4: With this answer. We have...we have our hall. Each...now we are using the new, each // each row they were 32 rows, there are 32 rows we have 32 rows, each row….each row has 18 chairs right? And if each row has 18 chairs then you are told {reading part of the question} right? So {drawing rows and columns} we can get the total, the total of this, of the chairs…yeah. The total of chairs in that hall and it will be 32x18 = 576. I am working according to my calculation. It won't give me 600, but, you see the question how it asks, a hall can accommodate 600 chairs. But according to the calculation here we found that the number of rows and chairs per each row will give us this if they are going to be equal. So if the total number of chairs are this (576) and 450 people are there, we can minus to find the empty chairs in the row (576-450=126). So this {126} are the number of empty chairs in this hall. But you are told per row and we know the number of rows are 32. So we can calculate in each row how many empty chairs are there and from there we can get our answer 126/32equals to 3.9375, 3 empty chairs {signaling the end of his working}.

R: Ok thank you, thank you that is it. I understand where you are coming from...and so we shall end there for now we shall discuss how you went through it tomorrow.

End of Clinical Interview

Reflective Interview Transcript for PS4

R: In this interview you look at, you reflect back; on how you did the task {PS4 nods}.

I would like us to start by first asking you what your impression about the task was.

PS4: Ok, the first time these types of questions, when you find it in an exam paper … always it is section B {second section of main examinations in KCSE} the first question.

Yeah it's always the first question … and that those are free marks.

R: Ok, do you mean algebra questions are always first in section B?

PS4: Ok, yeah, mostly.

R: Now that it's about a hall, so did it trigger any hall?

PS4: Yeah, about a hall, ok what I did I interpreted the question … Ok, I have my own format of answering a question and according to the way I understand the question, I see mathematics is easier you understand it when you do bits by bits and then you go to the next … and at the end of it all it will all make sense.

R: And now about the hall?

PS4: Ok, like a theatre, I thought of a theatre because they say there is fixed number of rows, right? … and in a theatre is where you find that chairs are fixed you cannot think of a hall like a … a school hall because you know a school hall, chairs are either forms or … you have to associate with a kind like a theatre.

R: Now, coming to the theatre what impression did it create?

PS4: You see if I am given like that that question, I picture myself in a theatre let's say a movie I am going to watch a movie, yeah. You always picture yourself inside there because when you sit, you, see that the columns are neatly arranged, the rows are neatly arranged now am trying to picture myself in it, then I say if those rows are … now I think mathematically but in the situation.

R: Ok ... Again when you read the question, you read it in English, was there any other language that came into play when you were doing the question?

PS4: Yeah, I read it in English but translating it, I did in Kiswahili.

R: And then you … when did you come back to English?

PS4: That is when I was discussing with you. If I was left alone I usually write a question then I speak to myself like; *saa naanza kusema hapa niko na two rows hapa na two rows itakuwaje* *hapa*? [Now I start saying, I have two rows, how will it be?] You see? That language more suits me and it's easier for me to understand the / question thus making it simple to do the question.

R: What if the question is given to you in Kiswa…? {PS4 interjected}.

PS4: That is very difficult instance … because in Kiswahili you see I have ever been given a question in Kiswahili and it's not as easy as it looks. You see am using my own words … . My own words that I know in Kiswahili to rephrase as it's called, ni kama [it's like] social Kiswahili. It is not written. Written and social are two very different things.

R: Kikuyu is your first language?

PS4: Yes.

R: Did do you use it here?

PS4: Aha! Ok, it is hard, it is hard, it is hard actually to translate. Ok, me the way I was brought up am, ok, I don't know Kikuyu as well as, but in school, if I were to explain now I have got a certain question and am explaining to someone, then I see this person is not getting when I use English when I use Kiswahili then I will tend to relate the question with another similar occurrence that usually happens, … kind like I tell him now in Kikuyu "ameenda kwa soko…[he/she is gone to the market] he is bought …" … as in I relate the question to make it, to make him best understand the question.

R: So Kiswahili is the home language that you use?

PS4: Swahili, Sheng, Swahili … mixture of Swahili and English.

R: Now, I also saw that you started by drawing, {recap from video} what you … you have said is the hall …, that is where you are drawing, why did you think of drawing and ... . There are algebraic ways of … {interjection by PS4}

PS4: Ok, you see when you draw, not only in algebra but in most questions; let's say it's hard to work out the question if you haven't pictured what it is about. You have first of all to picture it what it's about then from there you see the concentration of that question, will be based on what you drew and from there you can, you can be able to relate well with the question.

R: Ok, so geometrical way is an easier way to get to understand. Geometrical is where you are drawing, yeah. I also noted in the second part of the question you also drew, drew again {recap on drawing sections}.

PS4: Yeah, ok, what I do is that I ensure that what am doing in each and every step, what I am doing ok, I read the question then I get a brief idea of what the question is asking me. I portray it using a drawing, then I portray it using a picture which will enable me to relate well with the question then after that I interpret each and every sentence of the line, yeah. And I associate it with my drawing, then I work it out.

R: When you were relating {parts of the task} like the way you put it that you have an initial situation and the current situation, and you want to relate these two and there was six which was supposed to enable you relate. Did you do so in Kiswahili?

PS4: Ok, what I do like not always. There is a question you will get then you interpret it in English, then you find that you are not quite understanding. Then from there you translate it to Kiswahili, then until that point where you will say like, ooh … it is supposed to be this way. You can also go even to Kikuyu but I rarely do that unless it's a very hard question.

R: Ok, then you have also indicated that you can use Kiswahili {in questionnaire}, but there is nowhere I have seen Kiswahili used?

PS4: Yeah, that is because I was, if … sasa kama ungetuwacha na yule mwingine to discuss {if you had left us with the other student we discuss} that could be another instance.

R: But you see you had the option of discuss and explaining in Kiswahili.

PS4: Ok, you know it goes back in relationship it goes back in relationship you have with the person you are discussing with. For you we may call it professional relationship, for my other peer friend it's a normal, it's an open relationship I can even … we can even break in the middle of a question and tell him a story and go back to the question, you see it's very different.

R: Then … we come to your questionnaire I would like to refer there and you also use, you have talked about yourself about Swahili and *Sheng* with your friends. Now about the lecturers, do you speak to them Kiswahili?

PS4: I tend, sometimes let's say you are having an argument with a lecturer, like today there was an instance {in class} where the answer that the lecturer gave us wasn't proving itself, yeah. He told us something was a domain was a domain of something, then I was like it doesn't agree, then we had to improvise with Kiswahili because there reach a time that, I couldn't express myself in English. So I … expressed myself in the language that was best, I saw was best that could make lecturer understand what I was saying.

R: Now, in school, in the discussion groups that you have had, I want to assume that the rule in the school is to use English?

PS4: English and Kiswahili.

R: When you are discussing with other students in school, you also used to do it in Kiswahili?

PS4: Ok that // if it was in a discussion group, we had our own … that goes back to basics, we have our own objectives. If the discussion group like the one I had in high school, we used … we had a policy of speaking in English to boost our language and at the same time to boost our understanding and to communicate in English. So it was strict, but it was not a must, it was us as a group. But the others groups could even speak even in Kiswahili.

R: Thank you so much for your time. This brings us to the end of our interview.

End of Interview

Clinical Interview for S2

R: Go through the question, when you are ready to explain, inform me {works on the question for 13minutes where he makes a sketch of what seems to be rows and chairs. He signals he has finished and is then asked to read it aloud and proceeds to explain what the question required of him}.

S2: {Explaining from his written work}… so let the number of rows to be ***x*,** the total number of rows {gestures with his hand to indicate the arrangement of rows horizontally} has a total of 600 chairs. Then we are told that the chairs were rearranged meaning that, after rearrangement the rows will increase by 5, so I take (***x***+5), but the number of chairs per row is decreased by 6, so I have come to say that let the number of chairs be ***y*** in each row, so in each row there will be a decrement of 6 chairs after the rearrangement. So I have come to say that the number of chairs per row will be 600/***x***. Then after the rearrangement it will be 600/(***x*** + 5).

By that I have come to form an equation where I have said, 600/(***x*** + 5) = (600/***x***) - 6 {the 6 that were removed}. So I have solved it and I have got the number of rows were 20. I have got a positive number, meaning this is the one that I have taken {***x***=20} because the other one I have got a negative, there is no way you can have negative rows {he had worked out the negative value ***x***=-25 and cancelled it out}.

So after taking the number of rows, I have come to calculate the number of chairs in each row, I have found that it is 30. I have also calculated and found that after rearrangement, the number of chairs in each row were 24.

The second question {reading the first sentence loudly} so meaning if the first row was left for example 10 chairs, that should be the case for all the rows. So I have put it that after rearrangement, we have 25 rows {the ***x***+5}. These 25 multiplied, because we are told that the occupants have left equal number of empty chairs, it can either be sideways, or at the middle, wherever {gesturing the space of the empty chairs}, so if you take the number of people in each row multiplied by the number of rows you will get 450 people. So I took … let the number of chairs occupied be ***w*,** 25***w*** = 450, hence ***w***=18, meaning the number of people in each row, and I know that if we have 18 people in one row and we have the total number of rows as 25, meaning that the … // {inaudible} after rearrangement I found that each row should have 24 chairs {repeating the explanation for (b)} … meaning in each row, there are 18 people the remaining chairs will be 7.

R: 24-18? {He corrects to 6}. Does that bring you to the end of (b)?

S2: Yes.

R: Thank you so much for that session, I will call you for the next session.

End of clinical interview

Reflective Interview for S2

R: So when you read the question, what impression did it create?

S2: It's all about the, this unit somehow in algebra on how seats are arranged. First of all I saw the series, the topic of series and sequences. Even the first thing I thought, I knew even after reading the question I knew that there will be a quadratic equation. So after I read it fully, at the beginning I had seen as if I would use one of the formulae we use in series and sequences but after reading the whole question I saw that I will involve a quadratic equation so I will use the factor formula, the quadratic formula or the other formula to find the value of ***x*** in quadratic equations.

R: The question was written in English. Is there any other language that featured as you responded to the question?

S2: Usually in mathematics when solving problems you can't find a mathematical sum in Kiswahili or Kikuyu, so when I began studying I was taught English I had to go by that so that I could comprehend what the questions are saying. So if I read in English even in my thinking I will somehow think in English so that I can be able to connect the sentences and even the questions so that I can be able to reach at the answer.

R: And now that it was about a hall, what idea of a hall did you have?

S2: Yeah, I can imagine in a hall, for example in a theatre where you can go and watch a movie in town or acting for example those books in high school we used to hold such things whereby they could come and act. I somehow figured such a situation whereby we have such an audience coming to watch. It is not a must the hall to be full so I saw it can be a true situation so by that and by the things I have experienced myself am able to put it in the right order and come up with a solution.

R: So are you saying it {the theatre} helped you to figure out how to answer the question?

S2: Yeah, when I imagine of a theatre for example you can have a hall with a thousand chairs and you don't want to sit at the back you won't hear what the speaker is saying so you are forced to move forward. So the hall can be disarranged or rearranged in a way so that everyone can be seated ... {inaudible}.

R You drew a figure at one time here {pointing to the sketch}. What did it mean?

S2: I meant that these chairs in this question we are told that … I drew this figure to show me that this side there will be equal number of chairs and in this row there will be equal chairs left on this side and on the other side {illustrating with his hand}.

R: And do you do this often with algebraic questions trying to make some diagrams or sketches?

S2: If a question is involving such, I usually do.

R: There was also a time … {refers to the video} what expression were you trying to explain with the ... rows or? {in reference to hand gesture}.

S2: I was trying to show that {recap} some chairs left.

That was meaning that you know in the question we are told that the number of chairs in each row were decreased by 6 so I could show that if people were occupying in this place {showing an enclosed space with the hands} that other side is left empty {showing an arc to the back of the left hand} and that other side the same number of chairs is empty {similar arc to the right}. So I could use those expressions/gestures to show some emptiness on both sides.

R: Lastly, were there any challenges {language} that you experienced as you went about the question?

S2: Language? No … there was a problem when I read it the first and second time but when I started solving, it didn't pose {a challenge}, I went through.

R: It flowed well. Do you have anything you would like to explain to me more other than what I have asked you?

S2: I would say that in this sum first of all after reading the question, you should comprehend and try to figure out what the question is meaning. For example, when I read I first saw that / it was obvious here I will form a quadratic equation. That was my first thinking and my first note and that's why I started with ... I just went direct, let rows be ***x*,** because I knew I was to form a quadratic equation. So what I can say is the first understanding of the question is determines a lot ... by that time I would be doing the wrong thing and I would also be wasting time. You know in a mathematics class or examination time is a factor, a very limiting factor, so you waste time in one question it means you are also wasting time for the other questions you can end up not finishing the exam. So in mathematics we should be time conscious and try to do the sum with {as} little time as possible so that the sum can give the other sums time, and after that you can have time to review your work and correct the errors that are there.

R: That brings us to the end of our reflective interview. So I would only first of all thank you for being available for the two sessions. Your availability and even the willingness to be interviewed will go a long way in enhancing my research. So thank you so much.

S2: Welcome.

End of reflective interview

Reflective Interview for S11

S11 was introduced to the interview with snapshots from the clinical interview.

R: You read the question silently and then later I asked you to read it aloud. What kind of impression did the question create in you as you answered it?

S11: Ok, first I had to internalize, internalize and interpret internally so that if I could read now that's after interpretation, that's when I could go about the sum.

R: How did you go about internalizing?

S11: About internalizing… I had first to interpret internally to see what the question requires and what it needs from me before reading it aloud.

R: Did you have any language challenges as you read the question?

S11: Yes of course.

R: Which challenges were there?

S11: The challenges I can read it fluently but when it comes to matters of interpreting that gives me, it needs time. But the language I had no problem, but in interpreting I had to go slowly, step by step. But when it comes to answering of the questions that's when, discussing with you, that's when a problem may arise in my language.

R: The question focused on a hall, did you figure out a certain hall?

S11: No, no, no, no. I just imagined that a real life situation for instance we have, I have been to halls for example even our auditorium here. So I just took that picture that the arrangement could be somehow the same or could be related in some one way or the other.

R: Did it assist you in responding to the question?

S11: Yes exactly, because if I could not have been exposed or not have known an idea about that, I could not be able to have that picture of what am going to do about, of what the question is asking or what the question is.

R: That figuring out a similar structure did assist you in one way or the other.

S11: Because if I could not have known it could be something new. So at first before even tackling I could develop a phobia, 'ok I don't know this thing what does it, what's a hall…'

R: When you were interpreting, comprehending…were there other languages that came into play other than the English …in which the question is written?

S11: Ok, according to this question, as far as this question is concerned, the language that I had to use to interpret was specifically English, but if there are other questions that become difficult occasionally it may force us to some different language so that you can get exactly what the question requires.

R: So if the question is more demanding… {S11 interjected}

S11: Yes if the question is more demanding and the language that is used cannot be understood, according to me for example, I can interpret it in another language that I can easily understand.

R: Which is this other language that you do use?

S11: I can use Kiswahili or my first language.

R: Which is your first language?

S11: My first language is Ekegusii.

R: Which one comes much more is it Kiswahili or Ekegusii?

S11: As far as, to this extent {in the context of the question} Kiswahili.

R: Do you use Kiswahili much more than Ekegusii?

S11: Yes of course nowadays, but earlier on I had, I had, I was using that first language which was Ekegusii but I found that it really influenced me so much, it had some negative effect. So I had to…to change (Inaudible) and use Kiswahili.

R: To what extent do you use Kiswahili?

S11: You know our Kiswahili is not that perfect, we normally use that mixture Kiswahili/Sheng. But my Kiswahili I normally use when I…with friends when we discussing maybe some questions and when it comes to lecturers I normally use, depending on the kind of lecturer I might use Kiswahili or English. But normally I balance English/Kiswahili. But it comes to it comes to matters of friends I normally share ideas using Kiswahili that's the main language I use.

R: I can also see you use Ekegusii when discussing {referring to questionnaire}….

S11: Yes Ekegusii, Ekegusii when we meet for example people from home that's what we usually do. We cannot dig deep into that {Ekegusii language}, ok occasionally we may just relate, just relate in which we may use English/Kiswahili but if it may be difficult we may now dig deep into our language. Aii {exclaims}...for instance we have not been able to get this question {to understand a question} may be due to the language can we take it to the other side we see if we can get it.

R: Most of the work we have done here could be pertaining to this question and previous experience; at university level does the issue of how involving a question is make you switch to those other languages?

S11: No, no, no. To be genuine, occasionally at university level, you see there are times when things become tough. Word equations, especially word equations {referring to the question given} which we read paragraphs so that we have to interpret, in case I get some difficult ones. But for the meantime I have, I have not come across this kind of questions. What I know is that in future I will get them. So those ones will always demand that, if I fail to interpret in the language that is there I can always switch to the language that can help me understand the question.

R: Thank you so much for the information, the input you have given so far I really appreciate your effort and the time that you have used to come over this side, you have really enriched my study. As I said earlier on when I'm through with the analysis, the findings will e available to you on request. What other input could you probably have for this study now that you have been with me for some time, through the questionnaire, the first interview and now this final interview?

S11: About the language and relation to mathematics, yes, first you get that the language in most of the subjects to be specific in mathematics, you know you get that the language used there is

English. So you find that the language plays a very important role. In fact it plays the major role in how you go about a sum that's how you go about mathematics in general. So if you are not able to interpret or to get that language or to be well informed about the language, is used, it's difficult to tackle many questions in mathematics.

R: Thank you, I appreciate all that it will go a long way helping me put things in place and put up a good case for my study. Thank you so much for you availability.

S11: You are welcome.

End of reflective interview

Reflective Interview for S9

R: The question was about a hall and the arrangement of chairs. Did you figure out a similar situation?

S9: Yeah, okay it's like you have to make it a bit practical like as if you are really in sort of a hall, so you imagine of something that is happening.

R: What did you figure out?

S9: I imagined how a hall, with number of rows being equal and number of chairs per row being similar / same {indicating the hall in an outward manner and rows and chairs by moving his hand horizontally, with the chairs further indicated using the space of curved palm}. I was just being imaginative.

R: The question here was written in English and according to your questionnaire. Was there any time that you had to use other languages to go about it?

S9: Not really

R: So, tell me how you went about it in the language way through the question.

S9: Ok, the question I think it was using simple terms that never required a lot of thinking as in translating to your first language then after understanding you translate back; this was a simple one that could be understood.

R: In your earlier engagement with mathematics, are there instances in which you read a mathematics questions and you have to result to your first language?

S9: Yeah, there are some that you must actually imagine about from your first language then later translate back to English.

R: What situations make you change to your first language?

S9: / I can't figure out…there are cases…yeah…

R: How should a question be for it to make you result to your first language.

S9: You can imagine questions like may be somebody doing something like somebody going through a race, talking about the strides, that can make you think in the first language imagine how the strides can be, the length of the stride later on you can switch back to English.

R: So it's not about whether a question is tough or is demanding or easy?

S9: / Okay, you see even in a situation whereby you translate there must, may be a point that you are not getting you must actually take it to your first language and check whether you can understand. Yes, where there are terms that you must actually go back to your first language that is when you can get it over.

R: To end our interview... probably what would you say to this interview out of the experience you've had, the short experience you've had with this research?

S9: Okay, there are people outside there who might think that the language is the main things that can make you survive; provided you can be able to interpret whatever you are doing…I think it's just enough. You must not be a genius may be in English that is when you do well in mathematics. Provided you can interpret mathematical symbols and some...I mean the little language that you might have I think that is just enough because mostly in mathematics there are simple terms; and if not simple, the terms that are used are mathematically related to that particular situation.

R: Okay, thank you so much for that word and even thank you so much for your availability during the interview sessions.

End of reflective interview

Clinical Interview for S8

S8 read the question silently for 1.39 minutes, as he scribbled down some short notes and gestured with his fingers.

S8: Am I supposed to do it and complete it?

R: Yeah, you can do it to completion, if you first of all feel you want to do it on your own and then you explain, no problem; if you feel that we can go together I've no problem. Which way do you want to go?

S8: I'll first do it.

R: Okay {he works out the question for 8.16 minutes after which he signals that he has finished}.

S8: I'm through.

R: Okay, so I shall ask that you read the question aloud and then you shall proceed to explain. {He reads the question aloud then proceeds to explain his workings.}

S8: This question, because here we have unknowns, we have kind of like before the rearrangement we know that the hall had a certain number of rows and each row had a certain number of chairs. So you give the number of rows an arbitrary letter like ***a*** like I've done here {pointing where he had written}. I've said let the number of rows be ***a*** then, before the rearrangement, then I've said that because after the rearrangement the number of rows are increased by 5, so after the rearrangement the number of rows will be (***a***+5). Then we come to now the number of chairs in each row. The number of chairs before rearrangement we give it an arbitrary letter again like ***n*,** I've said it's ***n***. Then after rearrangement the number of chairs will be, because the number of chairs after rearrangement in each row had decreased by 6, so after rearrangement it will be (***n***-6).

Now from there you come up with an equation which says that now before the rearrangement, when you divide the total number of chairs that the hall can accommodate you divide by the number of rows you get the number of chairs. So it will be 600 you divide by ***a*** the number of rows you will get ***n*** {(600/***a***) =***n***}. After now rearrangement because the number of rows has increased by 5 and the number of chairs in each row has decreased by 6, you say that 600 divide by (***a***+5), which is the number of rows now, will give you (***n***-6) which will be the current number of chairs in each row (600/(***a***+5) = (***n***-6).

So from there now I've labeled them as [(600/***a*) =*n***] … (i) and (600/(***a***+5) = (***n***-6) … (ii).

From there we say now from equation (i), 600=***an***.

Now ***a***=600/***n***, I substitute the value of ***a*** in equation (ii), I substitute it with 600/***n*** now in equation (ii) because here in equation (ii) we have two unknowns and it's not possible to do [workout] a sum with two unknowns. So equation $\frac{600}{\left(\frac{600}{n}\right)+5}=n-6\ldots$ (ii) {which he simplifies to obtain $600=(n-6)(\frac{600}{n}+5)$ } … will have one unknown, which will be ***n.*** Now here ***n*** what you do you multiply both sides by this denominator {***n***} so that you can eliminate it now from being a denominator {***n*** in the denominator was however not eliminated at this point but later}.You expand the right hand side. After expansion of the right hand side, you get 600=600 - (3600/***n***) + 5***n***-30 … you take the like terms together… and obtain 30 = 5***n*** – 3600/***n.*** Then because here we are still having a denominator which is ***n*** in order to eliminate it, you multiply by ***n*** all throughout the equation … and you get 30***n***=5$\boldsymbol{n}^2$-3600 now this one is a quadratic equation {which he rearranged to get 5$\boldsymbol{n}^2$-30***n***-3600=0} so you solve it with either way of the quadratic equation. So I've chosen the formula because it's the most convenient and it will be easier and it's fast.

R: Which are the other methods that you can apply?

S8: You can use completing the square method, you can use the factorisation method.

R: Ok.

S8: So now because here you kind of have a common factor which is 5, I have divided all through by 5 so that at least the equation can be a little bit easier to work out. So I have divided by 5 to get $\boldsymbol{n}^2$-6***n***-720=0. So, applying now the quadratic formula, applying now the quadratic formula to get ***n*** you say {reads the formula, substitutes the values and works out to get the value of ***n*** for the positive, ignoring the solution that gives a negative answer, explaining that the number of rows cannot be negative}, so I've taken 30 to be the number of chairs.

R: Ok.

S8: So the number we are been asked for the number of rows. The number of rows now, because from the first equation we had said that if ***n*** is equal to … 600 divide by the number of rows you will get the number of chairs, so 600 divide by the number of chairs you get the number of rows. So 600 divide by 30 you get the number of rows will be 20.

R: Okay. That answers our first part or is it both?

S8: That answers our first part.

R: Ok. For (b)?

S8: {He silently reads and rereads the question and does calculations on the question paper for 6.09 minutes then proceeds.}. Now the second part, after the rearrangement we have now the number of rows will be number of rows will be (***a***+5) = (20+5) = 25. Number of chairs in each row will be (30-6 = 24). So now we are told {rereads (b) question} so 450 people, so the 450 people occupied every row but they have left some few chairs without people so what do you just do is divide 450 divide by 25 you get 18. So this 450 people on each row they sat on 18 seats and the total number of seats were 24 so minus 18 {computes for 24-18 as he explains to get 6 chairs} so on each row 6 chairs were left without anybody sitting on them.

R: Ok. That answers our second part?

S8: Yes.

R: Okay. So, thank you so much for that session, this is what I wanted us to do for this day then I'll invite you next week so that we may reflect on how you engaged with the task.

S8: {Nods} Yeah. Thank you.

End of clinical interview

Reflective interview for S8

R: When you read the question the first time was there any impression that you formed about it or about a situation?

S8: / Yes, because the first time I read the question, and even before reading the question I saw it was written “Algebra” so I kind of in my mind I was now prepared for something to do with unknowns and thereafter reading the question I was trying to think about which unknowns I would come up with.

R: Did you get an impression of any hall now that the question focused on a hall?

S8: Yeah, that picture came to me because that was like an auditorium or let’s say a theatre, just like an auditorium looks like; now you are trying to think that this hall has a certain number of seats, maybe it’s something kind of elevated like that {gesturing the elevation with his hands}, it’s flat you get that kind of picture …

R: Did it figure in your mind whether it is flat or it’s kind of inclined?

S8: I thought of it as kind of elevated because a theatre is kind of it’s flat but because people at the back couldn’t be able to see, in my mind it was already pictured that it is elevated {continues to gesture the elevation with his hands}.

R: Now, the question was written in English, did it at any one time as you read and interpreted … Were there other languages that may have come into play as you tried to read and interpret?

S8: Kiswahili only … even I found the answer using Kiswahili because now I was reading the question and interpreting it into Kiswahili and even these things I was writing I was saying wacha hii ikuwe hivi [Let this one be like this]{referring to scribbles on the question paper} so in Kiswahili.

R: Why did Kiswahili come into play?

S8: Because am mostly acquainted to Kiswahili as a language; am best in Kiswahili than in English. So it was the language that I was using to interpret now this. So, even though it’s written in English here {referring to the question paper} whatever was coming from my mind was in Kiswahili. I was just writing in English because it’s like a requirement.

R: So, yeah I can see your first language is Kiswahili and the languages that you use most at home; you have stated Kiswahili and then Kikuyu ... Kikuyu, was it coming anywhere?

S8: No.

R: At the start here {plays the video clip} at the very beginning there's an action. Look at that. What was that? {referring to his action of raising the little finger}

S8: There was something six. There was a six and I was showing the six .

In my mind now I was kind now like when reading the question the first time trying to understand it putting the figures on my mind, hii [this is] five {raising his fist}, hii [this is] six {raising the last finger} so when I do this it will stick. I know I did this {raising the last finger} there was a six somewhere.

R: When you were discussing assignments with your colleagues in high school which languages were you using, mathematics assignments?

S8: Mostly English and Kiswahili

R: And while here?

S8: We use the same, English and Kiswahili.

R: Which is more prominent?

S8: Mostly English because now you get most of the questions in English so when you are trying to explain how you do the sum to someone, you explain it in English so that when he or she comes across a certain question like that one she will be able to interpret in the appropriate language … here being English.

R: I can also see that with lecturers everything is in English or Kiswahili. Like when you are discussing your class work I'd like to understand it that probably you have a problem and you go to you lecturer do you use English or English and Kiswahili here and there?

S8: Mostly let me say that like now, I have seen a lecturer now twice or thrice, the moment you get in the office and say that I have a question here that is a problem to me maybe he sees something in Kiswahili, but when explaining the question to you he will explain it in English the whole of it.

R: And while in class?

S8: While in class, Kiswahili is just a bit, maybe just to break the monotony because mostly when the lecturers use Kiswahili, not most of them know a lot of Kiswahili so kind of people laugh so at least to excite you when he or she continues in English.

R: Ok, there is a moment I wanted to capture here {referring to the clip where the student reads the question through by pointing along with the pen and then counts with his fingers}. At that point, is there something you were calculating by so doing? {referring to the student's actions as he explains through, often using the word sum}.

S8: Eeh, no.

R: Ok, I appreciate your participation in the interviews. Do you have something that you would like to add to what we have discussed?

S8: No.

R: Thank you so much for being available to come for these two sessions of interview, I really appreciate and I know it will go far off in assisting me in what I need to do in my research.

S8: Welcome.

End of reflective interview

Reflective interview for S6

R: Do you remember the question?

S6: Yeah I do. The question demanded… to calculate may be given a number of rows in the room. And you are told that room has a number a certain number of chairs. You are told may calculate may be the number of rows that can fit in that room so as to so as to occupy the same number of seats given a room and the number of chairs.

R: Now that it was about a…you saw it at as a room, the question was about a hall, … Is there any impression it created in you about any room as you tried to interpret the question?

S6: / impression in what terms?

R: Like did you put it…was there an idea of any hall you have been to or a room?

S6: Yeah, I was thinking like something like a social hall, for example our auditorium.

R: Auditorium, what about it?

S6: You have a big room, and then we have, we have chairs arranged in rows.

In our room, for our case they are fixed. But you might go somewhere you find that there is a big hall and the chairs are not fixed. So…{inaudible} you give a way in to arrange those chairs such that they have certain number of rows[using hands to indicate arrangement in some parallel form, rows].

R: Did it help you in interpreting the question?

S6: Yeah, it did, but at some point I was confused because, sometimes the way the rows are arranged, maybe we have an order, maybe from the front going backwards we have a certain order. Now I got confused on 'how will I interpret it'?

R: Do you mean there are some rows with fewer chairs?

S6: Yeah, the way the chairs are arranged, from the front they go increasing backwards.

R: And the question was not exactly that way?

S6: Yeah.

R: As you read the question, [Recap], the question was written in English; were there other languages that may have come into play as you read and interpreted the question?

S6: Yeah, You know, I tend to … to internalize the question I put it in a language that maybe I could understand better. For example I understand Kiswahili better than English. Now I started putting the words in Kiswahili.

R: Which is your first language?

S6: First language I would say… Kikuyu.

R: Your first language is Kikuyu, but you find it easier to use Kiswahili?

S6: Because of my background, I'm from Rift Valley {one of Kenya's province occupied by people of diverse ethnic and language backgrounds}….I'm a Kikuyu but, I use a lot of Kiswahili.

R: Is that the language you had to bank on for interpretation?

S6: {Nods}.

R: Is it only Kiswahili that came into use because I can see you use English and Kiswahili with yourself? {from questionnaire}

S6: Yeah, I try to mix the two.

R: Tell me when you read the question, when does Kiswahili come in?

S6: May be when I don't understand well some point in English, now I try to relate the same, same question in Kiswahili I put the words in Kiswahili and start visualizing the whole thing.

R: We come to the end of our interviews; you have explained how you engaged with the task The information will shed light into my research. Thank you so much.

S6: Welcome.

End of reflective interview

Reflective interview for S10

R: Welcome to the second interview in which we reflect on some issues from the first interview that are of importance to my study. {runs snapshots of the clinical interview}
What was the experience you had with the question?

S10: Ok, after first seeing the question, I first, I didn't first think about the question I was thinking about them in university. I thought it were a very complex and it required university education. But it was very simple and it only required the knowledge from the secondary level. So I think we the students from the university, we complicate some questions while they are not.

R: The question was about a hall … did you figure out a hall elsewhere as you responded to the question?

S10: No.

R: The question was written in English, which is the examining language at the level that you did. I can also see according to your language background that you have Kikamba and also to some extent when you are at home, you use Kiswahili. Did other languages come anywhere in between when you were responding to the question?

S10: Yeah, yeah, yeah. First after seeing the question, in all my studies, I try to interpret in Kikamba which I'm more conversant with. I read in English then I interpret it in Kikamba, which I can understand more than English.

R: Are there particular parts or it is the whole question that … {you interjected}?

S10: The whole question.

R: How did you put it in Kikamba?

S10: I do it in Kikamba then I transfer to the paper in English.

R: Is it {the translation} something that you can write?

S10: No, no, no. Yeah, am more conversant with Kikamba more than any other language.

R: So if you are taught in Kikamba, mathematics in Kikamba {he laughs}…

S10: I think I could understand more than in English.

R: You read the question a number of times …{S10 interjected}.

S10: After seeing the question, first the question was very tricky, so I had to read it, reread it so that I can understand it more. Then in my translating to Kikamba and then to English, I think it wasted a lot of time.

R: Wasted time?

S10: Yeah…

R: You have said {earlier} it helps you to understand it better?

S10: It helps but it wastes a lot of time.

R: What would be the option?

S10: If it is possible, I can try to practice to interpret the question in English which I use to write in paper.

R: Then {recap}… I refer to the part where you were asking me if it is a must that we get 600. In doing the question did you face any language challenges as you did the question?

S10: No, no, no, it was very tricky but I understood it very well after rereading.

R: Then what would you say about this section? {Recap about a confirmation on total 600.}

S10: I was thinking about, I was thinking about whether it is a must because it was not written in the paper.

R: {Recap} … rows of chairs, what was it about, rows of chairs?

S10: Rows of chairs even after reading and rereading, it was very tricky. Rows of chairs, you know in the question there are chairs in each row and there are the rows. So in relating to know whether the question is asking about the rows or the chairs in the row gave me a problem.

R: And how did you undo that because you finally got the work right?

S10: Even after now rereading, asking myself the question I have told you I got the answer.

R: Thank you so much for your participation, we come to the end of our interview, but if you have anything you would like to put across for this interview then I would appreciate. Like a contribution or a question in the whole of what you have gone through since the questionnaire, the first interview and now this, our second and final interview.

S10: I would like to ask you, if now after … first did I get the final answer?

R: Ok, we had said probably the that initially we are not interested in the answer but the process you really go through and acquire something, the explanations you give, the reasoning you give, the kind of language you use, but I must say that you got the answer, though you started way off from permutations and you came to quadratics, you finally got the answer.

S10: No other.

R: Any contribution you would like to make beyond what I have been asking you?

S10: No.

R: Thank so much then, for being available, making your time to come. I'm wishing you the best in your studies and as I said in the consent form, the results of this study when they are out, anybody who asks I will post them to them, which will take quite some time.

End of reflective interview

Reflective interview for S15

The participant was informed of what was expected in the interview. An overview of the video covered during the clinical interview was shown.

R: When you first read the question, what impression did it create in you?

S15: After reading the paper you gave me, it had the square root, had the quadratic formula, so immediately {laughs} when I saw the quadratic formula, I knew I was supposed to form a quadratic equation and to use the quadratic formula.

R: So it's like the quadratic formula was already a hint.

S15: Somehow.

R: Did you link the hall in this question to any hall elsewhere?

S15: Not really, I only thought, I did not think about any hall in particular, but I just / visualized how it looks like, but it took me a while to picture it well / but later I was able to...to picture it well.

R: The question having been written in English only, was there other language that you used?

S15: I usually, when I read a question like this, I usually try to interpret it in my, my mother language for me to understand it well.

R: Which is your mother language?

S15: Kikuyu. Then I bring it back {laughs} and represent it in mathematics.

R: Do you do that for the whole question or some parts?

S15: Let's say a whole question because I have to picture, I have to picture the question, think of how those chairs and rows are arranged then try to suit myself in the language that I usually understand well. Generally is like the whole question.

R: So that time you were explaining to yourself, in what language were you explaining to yourself in?

S15: Mainly Kiswahili and… Kikuyu, but not deep Kiswahili.

R: Is it something that you can write? {referring to the translation that was made}.

S15: I don't even know how to write Kikuyu {laughs}.

R: But you know how to / to speak it?

S15: Yes.

R: Anything else you would like to add to this interview with regard to language and mathematics?

S15: In mathematics, what I would say is that in any question just translate it to the language you understand. Visualize it in your mind. When you get the picture when you understand what you are being asked, what you are being asked for, then you go back to write in mathematical, mathematical you know English. That's all.

R: Thank you so much for being available and even the information you have given me, it will go a long way in helping in my work.

S15: Welcome.

End of reflective interview

Clinical Interview for S3

R: What does the question require?

S3: / so the total number of chairs {writing} total number of chairs is 600 / then each row has the same number of chairs. If it is 20, 20, 20 ... per row is the number {reading from the question, he continues}, so you just let the original number, original number of rows before the increase of rows be a value let's say $\boldsymbol{x}$. So after the increase the new number of rows is now ($\boldsymbol{x}$+5), yes, after the increase. But the number of chairs per row is decreased by, by six. So if there are $\boldsymbol{x}$ rows initially and the chairs the total number of chairs are 600 it means that the number of chairs per row in this will be $600/\boldsymbol{x}$.

R: That is the number of?

S3: The number of chairs per row, before the number of chairs … before the increase. So after the increase number of chairs per row is going to be $600/(\boldsymbol{x}+5)$ / after these changes have been made, the number of chairs per row is decreased by five.

R: By?

S3: By six {corrected to six}. So therefore it means that, this one {$600/\boldsymbol{x}+5$} is more than this one this value {$600/\boldsymbol{x}$} by 6 {referring to $(600/\boldsymbol{x}+5)-(600/\boldsymbol{x}) =6$} … so we form an equation here …

R: Which value did you say is bigger than the other one? … Just start again which is greater than the other one between these two {in reference to ($600/\boldsymbol{x}$ and $600/(\boldsymbol{x}+5)$}?

S3: Ok, this value is greater {$600/\boldsymbol{x}$} is greater than this value {$600/\boldsymbol{x}+5$}, so we take this minus $(600/\boldsymbol{x}) - (600/\boldsymbol{x}+5)$ not the other way round {making the correction}. We have $(600/\boldsymbol{x}) - (600/\boldsymbol{x}+5) = 6$. Now we multiply by the LCM (Least Common Multiple) which is $\boldsymbol{x}$ into ($\boldsymbol{x}$+5) {written as $\boldsymbol{x}(\boldsymbol{x}+5)$}. … We get $600(\boldsymbol{x}+5)-600\boldsymbol{x}=6(\boldsymbol{x}^2+5\boldsymbol{x})$ so our aim is to get the real number of … rows {proceeds to simplify} … we make it to be simple, we get $\boldsymbol{x}^2 + 5\boldsymbol{x} -500=0$. So we solve this quadratic equation. So we can use the formula {writes down the formula and works the value of $\boldsymbol{x}$ as he explains} so our $\boldsymbol{x}$ is just 20 or -25. Yes, so we said that we let the … {rereads question (a)} and we said that let the original chairs of rows be $\boldsymbol{x}$ so that is the value of $\boldsymbol{x}$.

R: 20 or -25?

S3: We ignore -25 and take 20. Yeah, because chairs {rows} cannot be negative. Then part (b) … {rereads part (b) of the question aloud with 450 read as 650}.

R: Read that again, how many people?

S3: … ah, 450, {proceeds to read the question}. So after the rearrangement … the number of rows were (***x***+5) because we are being told that the chairs are rearranged such that the number of rows is increased by 5. So the number of rows after rearrangement was these ones {(***x*** + 5)}, but the value of *x* is 20 so the number of rows after the rearrangement is going to be … 25.

{Rereads part (b) of the question aloud} so the total number of chairs is 600. So it means that if 450 people were seated in the hall, the number of chairs remaining is 600-450=150. So 150 is the number of chairs remaining and each number of chairs remaining are distributed in 25 rows. So it means that each row, each row is going to have 150/25, yes which is 6 chairs per row.

R: Okay, that winds up what you have for part (b)?

S3: Yes.

R: Ok. Thank you so much for that session. Later on we will reflect on how you did it.

S3: Ok, thank you.

End of clinical interview

Reflective Interview for S3

Video Recap

R: When you read the question alone {silently}, what impression did it create in your mind?

S3: First of all, when I read the question I looked at it and I tried to relate it to real life situation. When I / I read it further, I imagined myself arranging that … {inaudible} maybe somebody has been appointed to arrange chairs in a certain hall. I was imagining if it were me, what could I do?

R: A real life situation …?

S3: It's like there is a meeting in a certain hall, and maybe the guests have been invited and everybody. So the chairs are supposed to be arranged maybe I'm there and, I can be consulted / to arrange those chairs. So I was imagining, I'm the one to be appointed to arrange those chair, what could I do?

R: Did that {real life situation} influence how you solved the problem?

S3: Yes, in that, I was now seeing things like physically not like on the paper, because when I was focusing, the chairs as objects. That really motivated me, helped me a lot in solving that question.

R: Being in that real life situation, did it prompt languages used in such settings?

S3: It prompted to some extent in that the language used was something like object, object language, to do with object.

R: Tell me more about that one.

S3: You find that the objects were now chairs, the chairs can communicate something.

R: {Paraphrasing the question on languages, R asked} The question was written in English, as you read and went about doing it, did you at any one time use other languages?

S3: {Laughs} in interpreting that question, yeah, to some extent. For deeper understanding of the question, when I read it I tried to interpret it in my language which is Luhya. I tried to translate the words written there in Luhya using my brain.

R: Are there specific words that you may have used that are in Luhya?

S3: Yes / like chairs is "izidindeve", "Izidindeve" are arranged in rows meaning chairs arranged in rows, arrange is "kubang'a". When I had these two words, I now know that, I had the deeper meaning of this question, because I understand this language better, it's my original language, the language that I learnt.

R: Much as you understand the language (Luluhya) you preferred to be interviewed in English.

S3: {Laughs} The language I thought that the English is the most official to be used in interviews.

R: Otherwise,

S3: If they could allow {laughs} for any other local language then I could choose on this {Luluhya}.

R: That brings us to the end of the interview, but probably there is something you would like to add to what you have seen so far, at least what am looking for … what would you say to this interview?

S3: // If research is to be conducted, we must involve all spheres, all students, maybe the students at the lower stage, at the upper and the middle level so that we can get different opinions from them.

R: What do you mean by lower stage, upper and middle?

S3: The students who are performing best in mathematics, averagely and those who are trying must be involved so that you can see their response.

R: Thank you for that contribution … and for being available for the interview. We have come to the end of the interviews.

S3: Welcome.

End of reflective interview

Reflective interview for S4

Recap of previous interview

R: When you read the question, what impression did the question create in you?

S4: Impression?

R: Yes kind of thoughts…

S4: I did everything as was in the paper

R: The question here was written in English… as you read the question and responded, were there other languages that were coming in between?

S4: Yes a bit of Dholuo.

R: How did that go?

S4: In the interpretation of the question.

R: Were there particular words or phrases that you were interpreting using Dholuo?

S4: Yes, like the case where the rows were decreased by 5 and the number of chairs per row was increased by 6. So I understood that and relating in mother tongue.

R: How do you write that... like which phrases?

S4: This phrase where you are saying you increase by 5 and decrease by 6 {referring to the question}.

R: How did you translate that to mother tongue?

S4: I was saying that…should I say in Luo?

R: Yes

S4: So we say that ‘The chairs are rearranged such that the number of rows increased by 5’, so in mother tongue we say that ka imedo chair …

R: So what is 5?

S4: ‘5’ is ‘abich’ and ‘6’ is auchiel.

R: Would you mind writing the translation that you used?

S4: I read this in English {the first two sentences} and then translated from here {and writes the translation from the third sentence} ‘ka imedo rows a abich to igolo kombe auchiel e kila row. Ibro dong gi rows odi gi kombe adi e kila row.

R: Okay, so that’s the third sentence, why did you put it in Dholuo?

S4: To understand it better. I saw it as much complex so if I put it in Dholuo I saw it a little easier.

R: Do you often do this?

S4: I do it not often. Sometimes it comes sometimes I don't do it

R: And it actually helped you interpret and get to the point that you wanted?

S4: When I was first interpreting then later switched to English

R: And you were easily able to translate back to English?

S4: Yes

R: We come to the end of our interview. Do you have anything to add to the research that am carrying out?

S4: I think it's kind of good exposure, it's rare to get such an interview.

R: Is there any way that this kind of a research… on language can assist you as a student?

S4: It enlightens us, kind of the strategies you put into it, like what do you look into it, how you read and interpret {the question} even in mother tongue.

R: Thank you so much. I appreciate your effort and even the time that you o attend to the interviews here, I'm very grateful.

S4: Okay

End of reflective interview

Clinical Interview for S14

R: Go through the question first, then when you are ready to explain how it can be done, let me know.

S14: So will I be explaining as I do?

R: Yes first read aloud {S14 reads the question aloud}.
What is the question requiring you to do?

S14: The question requires me to / employ the idea of quadratic to solve / the number of rows and the number of chairs.

R: How do you know that it requires you to use quadratic methods?

S14: I come to realise that you can at this level / we are told that {reads aloud} the number of chairs is increased by 5 but the number of chairs per rows is decreased by six. The first scenario, we are going to let the number of rows to be ***r*** and then the number of chairs I may say to be ***c*** so in the second scenario ***r*** is now increased by five you take (***r***+5) and then number of chairs now when you subtract six since it has been decreased. So somehow naona kama inaleta [I see like it will result in] quadratic equation.

R: Then I think we can proceed to do it as you explain how you do it.

S14: So let the number of rows be ***r*** {continues reading the question}, each row … so when you increase the number of rows by five you will have **(*r***+5) but the number of chairs per row is decreased by, by six. So if originally we had ***c*** chairs so this scenario is going to be (***c***-6). So find the original … so the number of chairs altogether is 600. Ok / you can say ***c*** {he goes ahead to calculate as he explains and gets a quadratic equation} … so take ***c***(***c***-6) = 600.

R: You have multiplied the original number of chairs and the new chairs.

S14: Yes … to get $c^2 - 6c - 600 = 0$. Then applying the quadratic formula, you can use the quadratic formula or the completing the square method. I'm using the quadratic formula. {Writes the quadratic formula and substitutes the terms with their respective values and calculates to get ***x*** *here* ***c,*** as 27.68 and -21.68}. In this case since we are finding the number of chairs, we are going to discard -21.68 since the number of chairs cannot be negative. The realistic number of chairs, we cannot as well take 27.68 because the number of chairs must be a serial number so they should be 27.

R: We needed the original number of rows in the hall {S14 reads (a)}.

S14: Find the original number of rows of chairs in the hall {reading the whole question again} it's confusing ... .

R: Just read it again ... take your time.

S14: {After reading he requests}I can redo it? {R nods and S14 proceeds to interpret the question reading loudly and writing.}

R: Could you read the first and the second sentence again.

S14: "Each row has the same number of chairs".

R: Interpret that and tell me what it means.

S14: … the total number of chairs in the hall is 600 … these chairs now {are} arranged again in rows such that each row has the same number chairs … .

R: What does that mean?

S14: From there we can get the number of chairs in each row. If we had $\boldsymbol{r}$ rows and the total number of chairs is 600, it means each row can accommodate $600/\boldsymbol{r}$ chairs. If we increase the number of rows by 5, then each row has $600/(\boldsymbol{r}+5)$ chairs. So there is a relationship between $600/\boldsymbol{r}$ chairs and $600/(\boldsymbol{r}+5)$ chairs in that we are told that the number of chairs decrease by 6. So we have $600/\boldsymbol{r} - 600/(\boldsymbol{r}+5) = 6$ {he proceeds to simplify the equation up to $6\boldsymbol{r}^2 + 30\boldsymbol{r}-3000 = 0$ then says}…we want to form a quadratic equation so we can divide through by six … ending up with $\boldsymbol{r}^2 + 5\boldsymbol{r}-500=0$. So we can now identify $\boldsymbol{a}=1$, $\boldsymbol{b}=5$ and $\boldsymbol{c}= -500$. So applying quadratic equation to solve for $\boldsymbol{r}$ {he proceeds to substitute the coefficients into the quadratic formula and to solve for $\boldsymbol{r}$ to get the value of $\boldsymbol{r} = 20$ or $\boldsymbol{r}= -25$ and proceeds} $\boldsymbol{r}$ was representing the number of rows, the number of rows cannot take a negative {value} so the realistic value of $\boldsymbol{r}$ is 20, so there were 20 rows. "After the rearrangement…calculate the number of empty chairs per row". We can say let the number of empty chairs in each row be $\boldsymbol{c}$**.** The number of empty chairs was $\boldsymbol{c}$**.**

R: The original?

S14: I'm now using the new conditions, that the number of chairs to be **c**. So if we // had rows then the number then it means that the total number of empty chairs that will be left if each row tukona [we have] $(\boldsymbol{r}+5)$ then we multiply by $\boldsymbol{c}$ to get the total empty chairs. We know $\boldsymbol{r} = 20$ so $\boldsymbol{c}(20+5) = 25c$. {After working for about 9 minutes} We shall equate it $(600 - 25\boldsymbol{c})$ to 450. We shall have $600 - 25\boldsymbol{c} = 450$ … hence $\boldsymbol{c} = 6$. Answer itakuwa tu [will be] six.

R: Ok. Thank you so much. So this session was meant for just doing the question, I will invite you later on so that we can look at how you went about it.

End of clinical interview

Reflective interview for S14

Video recap to familiarise the participant with the clinical interview

R: What experience did you have with the question?

S14: Experience? I have encountered such questions earlier on.

R: What experience did you have with this particular one?

S14: With this one ... {inaudible} it was just ok but I could not comprehend it at first. I was trying to do it; I eventually realised that I was not understanding the context in terms of the English ... {inaudible}.

R: Like in what area could you not understand the language used?

S14: I was just confusing some rows, the chairs, I could not internalise it to come up with the right thing in the first attempt.

R: But later on ... ?

S14: Yes later I was able to do it.

R: What was the bridge? How did you come to realise how you were supposed to work it out?

S14: I had to give picture framework of the question. I gave a mental picture.

R: Can you describe it?

S14: I imagined first that the rows, there were 600 chairs. Each chair was supposed to accommodate one person, that was also the time I was doing the second part of it, each chair was supposed to accommodate one person, yeah.

R: And that framework is the one you used to proceed on especially as you say in part (b)?

S14: I was able to solve part (a) but when now it comes to part (b) I got a problem. So I had to again to imagine that each chair was supposed to accommodate one person. Initially when I was solving it I gave a wrong impression that they were benches, I took it in terms of benches. So when I took it critically I realised that these were chairs and every chair was supposed to accommodate one person.

R: As you did that, were there other languages that were coming into play as you moved from one point to the other?

S14: Yeah there was Kiswahili, some mother tongue [laughs].

R: Tell me more about how you involved them.

S14: I involved it {here he was referring to Dholuo as may be seen in the later utterances} at the stages where I was not able to interpret in terms of English.

R: Like which parts?

S14: I can go through it, ama? [or?]

R: Yeah, you can. {He reads the question and proceeds to interpret part of (b)}.

S14: In part (b) I had to involve, I was a bit confused in terms of these people (450) and the number of seats here. I had to involve Dholuo and Kiswahili so that I interpret that each chair was supposed to accommodate an individual. So depending on the equation that I got in part (b), so I had to equate to the number of people so that I could solve it.

R: So did you translate the whole of part (b)?

S14: In mother tongue? Yeah.

R: How did it go like, if you can write? {S14 writes the translation of part (b) in Dholuo and then reads it aloud}.

S14: Ka ji 450 obedo to gi wuoyo kombe, kombe ma odong' onego bed ni ting'o ji 150. [If 450 are seated and they rearrange the chairs, the remaining chairs should accommodate 150 people]. I set out the equation for the remaining chairs ... {inaudible}.

R: And that assisted in getting back to the solution?

S14: Yes because in stage (a) I was now having the equation, how I could put it so that I solve it for the number of empty chairs that was where there was a problem.

R: There was also the mention of Kiswahili, tell me how you used it in this question.

S14: Kiswahili I used it almost throughout.

R: Tell me how you used it.

S14: I used it when I was referring to the numbers here like 600, like six, like five.

R: Why do you use Kiswahili for the numerals?

S14: At times

R: Why?

S14: That one I’m not able to explain.

R: Does it mean every other time you see numerals you read them in Kiswahili?

S14: I always tend to read them {in Kiswahili}.

R: So even when you are reading this {quadratic} formula here, that 4 … {referring to constant value 4 in the quadratics formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ }

S14: But not such cases only; at times ndio natumia [it’s what I use] ... and I actually think maybe because I’m living with people … {inaudible} so most of the time we speak Kiswahili.

R: The question was about a hall; did you associate the question with a hall somewhere?

S14: Yeah, I had to.

R: Tell me about it.

S14: Church hall especially the Catholic Hall where we are staying, I imagined such halls.

R: Are there similar arrangements?

S14: There are chairs which are arranged {in} rows and columns.

R: And did it assist you in doing the question?

S14: Yeah, it assisted me in doing the question.

R: Does it relate with the … picture framework?

S14: I had to recall that picture framework, in most of the questions I have to form a picture framework.

R: What would you contribute to my study?

S14: I think it is a very important factor when it comes to mathematics. We have to comprehend the question and if you do the wrong interpretation especially when somebody diverts from English and then brings another language, let's say mother tongue or Kiswahili, it may bring a different interpretation apart from what was expected. So language is very important especially English is very important for mostly performing mathematics.

R: A point to note. But it contradicts what you have already done now because for you interpreted and translated to mother tongue and you were able to succeed in that question.

S14: So what I can say when you now divert to other languages apart from English then it consumes a lot of time. If you understand English better you can understand the question and then do it within the expected time.

R: Otherwise if time was not a problem.

S14: Somebody can just interpret it to any other language.

R: We come to the end of the interview now. I appreciate your participation and the inputs that you have given; they will go a long way in helping me in my study. Thank you so much. I am wishing you the best in your academic performance and also social life.

S14: Thank you.

End of reflective interview

Clinical Interview for S13

R: I would like you to go through the task and once you are ready to do it then you will tell me so that we can proceed. {S13 reads the question silently and then aloud.}

So what does the question require of you?

S13: The question first / you have to understand / what it is what it is talking about. The first thing it is talking about number of people that ... {rereads part of the question} … the number of chairs that can be accommodated in a certain room /. Then after understanding that point, then, ok the question is talking about "how are these rows?" because these chairs they can't come just there, they are arranged in a certain order {he gestures the arrangement of the rows using his hand}. This order, each row has the same number of chairs. Then after the number of the chairs, after the number of rows there is the ways the chairs are arranged in each row. Then the number of chairs are rearranged such that the number of rows is increased by five but the number of chairs per row is decreased by six. So I think the first thing is we can write the inform … {inaudible} interpret that information in a way that we can understand.

R: You can proceed.

S13: So if we have we have our / {rereads part of the question} that is the total {rereads} kwa hivyo [so that] if we have $\boldsymbol{x}$ {explains as he writes} let, let the number the number of rows be $\boldsymbol{x}$ because we doesn't know them. Let the number the number of chairs in each row in each row be $\boldsymbol{y}$. That means if we take $\boldsymbol{x}$ multiply by $\boldsymbol{y}$ if each rows each row has the same number of chairs, if we take this one {$\boldsymbol{x}$} multiply by this one {$\boldsymbol{y}$} we are going to get the number of chairs in the hall which is equal to 600 {he writes $\boldsymbol{xy}$=600}. Then {referring to the question} so the number of rows are increased by five but the number of chairs they are decreased by six {writes} / so from there we can be able now to form two simultaneous equations then we solve.

R: Ok. Go ahead.

S13: So we are going to say {rereads part of the question "the chairs are rearranged…"}, so we want to get the original number of rows and the number of chairs. So we are going to / work out / this way. We know that even these one {referring to ($\boldsymbol{x}$+5) and ($\boldsymbol{y}$-6)} if we multiply then they are supposed to give us the maximum number. So ukuje useme [you say] you come and say {explains as he writes} 600 is the same as ($\boldsymbol{x}$+5) multiplied by ($\boldsymbol{y}$-6) {($\boldsymbol{x}$+5) ($\boldsymbol{y}$-6) = 600}//.

So from here we can multiply out and then let us let us make the first one we make $\boldsymbol{y}$ the subject. So it is going to be $\boldsymbol{y}$ = 600/$\boldsymbol{x}$. Then this one {the second equation} when multiplied out we get $\boldsymbol{xy}$ - 6$\boldsymbol{x}$ + 5 $\boldsymbol{y}$- 30 = 600. Then but, but we know that **y** is equal to this value {referring to

600/**x**} so we can substitute. So where there is **y** we substitute with 600/**x** so we are going to get $x(600/x) - 6x + 5\ (600/x) – 30 = 600$. {He proceeds to calculate. First he simplifies the equation to get $600\text{-}6x+3000/x\text{-}30=600$. Then he goes further to get the LCM and simplifies to $600x - 6x^2 + 3000 = 600x$ and further to get $6x^2 = 3000$}. So we divide by six divide by six we get $x^2 = 500$ //.

R: Where did this one go {referring to -30 in the expression $xy\text{-}6x+ 5y\text{-}30=600$}.

S13: Oh, this one? {He silently checks his calculations} 30 multiplied by…

R: Am trying to find out where it went because I can see this is 5**y** which is … this {pointing at $5(600/y)$}...

S13: This one is the one which is missing {highlighting 30 by underlining it in the previous equation. He makes the correction to get an equation $-6x^2\text{-}30x\text{-}3000=0$} we can form a / a quadratic equation. So this one divide by negative everywhere so you will get … {R interjected}.

R: I would like to understand this sign {following from the immediate step referring to -3000 in the equation $-6x^2\text{-}30x\text{-}3000=0$}

S13: Ooh, it was negative, it was negative so it will become positive.

So you get $6x^2+30x+3000=0$ {making the mistake again of +3000 instead of -3000}. So you have, let us use the, we can first divide by 6 but we can use the, what we call the quadratic equation {writes down the formula}.

R: What do we call that one? What do we call this one? {In reference to the quadratic formula which he had called quadratic equation}.

S13: This quadratic equation, {corrects to} quadratic formula.

R: Proceed.

S13: In this one we are going just to substitute. {He substitutes the values into the formula then says} there is a mistake somewhere // there is a mistake somewhere.

R: Why do you think there is a mistake?

S13: Because when I subtract here it is going to give us a negative value {in reference to the substituted values under the square root sign}.

R: Ok. Then try to identify where that could be. You did not expect any negative value there?

S13: Yeah. Mmh, let me first feed {he substitutes into the formula}. Let me see how {calculating}… there is a mistake somewhere.

R: Ok, just check and see where you might have gone wrong.

S13: Cause hapa [because here] you are not supposed to get that negative value.

R: Okay, just check, and see.

S13: Okay {goes through his work comparing with the question. First he calculates silently for 2.12 minutes then proceeds to calculate as he explains changing the format}. We work out in this format $\boldsymbol{xy}$ = 600 meaning $\boldsymbol{x}$ =600/$\boldsymbol{y}$ and 600/($\boldsymbol{x}$+5) = ($\boldsymbol{y}$-6) {then substitutes for $\boldsymbol{x}$ in 600/($\boldsymbol{x}$+5) = ($\boldsymbol{y}$-6) simplifies and finally obtains $6\boldsymbol{x}^2+30\boldsymbol{x}-3000=0$} in the other one it was the sign {commenting on an earlier mistake}.

R: Ok, it was the sign that was a problem?

S13: Yeah. Then this one we divide by, we use now this formula {the quadratic formula}, which is… {substitutes the values of the formula with those of the equation} the value of ***b***, our ***b*** is equal to 30 so itaku{wa} [it will be] it will be -30, it is going to be -30. So we can feed our calculator directly {calculates}. After working out this finding the square root we are getting it is equal to 270. So we have -30 plus or minus 270 divide by 12 is equal to $\boldsymbol{x}$. So because chairs cannot be negative this is plus or minus, let us take the positive value. It's going to be -30+270 you get 240 divide by 12, this one you get 20 so our $\boldsymbol{x}$ is equals to 20.

Because we have managed to get the value of $\boldsymbol{x}$ we can get the value of $\boldsymbol{y}$, which is equal to / $\boldsymbol{y}$=600/$\boldsymbol{x}$ … so our $\boldsymbol{y}$=30. So the original values of the number of chairs and the number the original number of rows was, the number of rows was $\boldsymbol{x}$ so it is $\boldsymbol{x}$. the original the original number of, of number of chairs in each row was 30.

Then we go to second part {reads the part (b) of the question aloud} // Now it is after we have arranged all the chairs in this order. Now we have after rearrangement the new number of the new number of rows it will be ($\boldsymbol{x}$+5) which is (20+5) = 25. The new number of chairs in each row it will be (30-6) =24 // after getting these are the number of, after rearranging it {rereads the question}. So this number of people once they are sitting they have seated {rereads: "Calculate the…"} so in total we have we, we had 600 chairs and each person is going to sit in each chair. So how many chairs which are not going to be occupied? They are going to be 150; they are going to be 150chairs which are not going to be occupied.

R: How did you get the 150?

S13: You take 600 you minus 450 because these are the number of people, and we do expect each person is going to sit on each chair. So we have 150, these are the empty chairs.

Now we want to know how many empty chairs were there in each row. Then we are told the same … once they are seated they are going to leave the same number of empty chairs in each row.

R: Yes.

S13: …and how many rows do we have? The number of rows now we have 25. That means if let the number of empty spaces in each row be now ***k*** another constant that we doesn't know and we know that we have the number of rows which is 25 and these are the empty chairs that are going to be left, so we can be able to get ***k*** because it is constant in each row we are going to leave ***k***, ***k***, ***k***, … . So we are going to take our 150 divide by the number of rows so that we can get our ***k***. So it is going to be 150 divide by 25 we get seven is it 7? No six {confirms with a calculator} so… ***k***=6, in each row they left 6 chairs which was not occupied.

R: Ok, thank you so much for that elaborate explanation. Our session today was meant for us to just do the question. Then I will invite you to discuss with me how you went about it.

S13: The same question?

R: Yeah. But now you will not do it again. We shall discuss how you went about it among other things.

S13: Ok

R: Thank you so much.

End of clinical interview

Reflective Interview for S13

The session started with a video recap showing an overview of how the student proceeded with the clinical interview.

R: You read the question tell me about it.

S13: For one, when you, the first part when I was reading it, when I was silent, I was trying to get is "what is the question trying to ask?" and I could visualise it in my own language, because / this language is not so … is not haikuangi ati common kwa kila mtu ['it (English) not common to everyone']. So at a certain point I could read the question if I have not understood then I try to figure out, "what does it mean?" If I'm given about this information, now I have to digest this information bit by bit in my own language. Then / from there after I have understood, after I have understood now the question, I could now be able in a position to write or answer the question.

R: You mentioned that you usually visualise it in your own language, which is this own language?

S13: Most of the time {laughing shyly it} I usually, I usually … after I read a certain piece of question, I have to think it in my language now, my first language.

R: Which is your first language?

S13: My first language is Kikuyu {laughing shyly}, now after thinking in Kikuyu then I could now go to the question, now I have understood in a way that I can now react to the question what it is asking.

R: Does this happen always?

S13: Most of the time, if for example you can give me a question I lack to understand in a way that I can speak it in my own language, most of the time I will not be able to answer that question properly.

R: In this question, did you do that throughout or it is in some parts that you had to engage in your first language?

S13: For example in this part, I could read this one {referring to the first sentence in the question} I know what is talking about in my own language. Then after the first sentence then I continue {with all other sentences} then I can get the real picture of what the question is talking about. For example here, {reads the first sentence}. Now I could ask I could visualise in my mother tongue, this is 600 / how could they be arranged? Yes, they are in a room but how could they be arranged? After I think it in my own ways now I come back to the questions after I have understood what is in me.

R: Is it something you can write?

S13: Yeah

R: Would you mind writing it?

S13: I write it in my own language? {R nods. S13 goes on to write the information part of the question in his mother tongue and then reads it aloud}.

Nyumba iganagira itĩ magana matandatu ibangitwo na mĩhari. Omũhari ukoragwa na itĩ ciganaine. Itĩ ni ciabangurirwo na ikibangwo ringĩ, na itĩ iria ciari muhari umwe ikinyiha na ithathatu na mihari ikiongerereka na ithano. [A house/building has a capacity of six hundred chairs arranged in rows. Every row has an equal number of chairs. The chairs were rearranged, and the chairs in each row reduced by six and the rows increased by five].

This is how now I understood the question in my own language. Now this is how I understood it in this format, after I understood it in this format, I could now translate this information in now in English, in my own way.

R: Then you are able to proceed to answer the questions now in English.

S13: Yeah.

R: At certain times as you went about you used other languages.

S13: {Nods} Yeah, mostly I usually use Kiswahili.

R: How does it feature into your work, as you do it? I have record of four times that you are using Kiswahili {recap}. What role did it {Kiswahili} play {in responding to the task}?

S13: This one maybe after understanding it in this way {in reference to the Kikuyu translation}, because Kiswahili is the language which is closer to my language, now I come to use it severally.

R: When you are talking or when you are doing the work itself?

S13: When I’m working, especially when am working. If it’s come on mathematics or may be sciences, I will have to think in those two languages, I read in this one {English}, then in the process I will come now to use this Kiswahili in the meanwhile.

R: Do you usually plan to translate?

S13: No, it comes naturally.

R: The question was about a hall, and I wonder whether you figured a hall in any particular context.

S13: Yeah, the first thing after getting the word hall, there is a something that came in my mind // "this is a hall, where have I seen a hall?" And after visualising where I have seen a hall, may be a church or somewhere we go to a lot of gathering, now I could, I could now think how these chairs could be arranged in that big house.

R: Was there a particular hall or you thought about them broadly?

S13: Yeah, for example in this case, because we are just near the school {university}, the first one that came in my mind was this auditorium. You can see those rows, now you can place those types of chairs … that you can arrange. And you can see that hall those desks are not of the same length. Now what came in my mind was a hall like that one.

R: Thank you for the information that you have given me out of the questionnaire, the clinical interview and this interview. I don't know whether you have a question pertaining to the same that you would like to ask me.

S13: What I can say is that the language may be when you talk about language of education or learning it matters a lot. Because each one of us will understand ones you get a question especially an exam question, if you lack to understand that question, in a way that you are supposed to understand, automatically you usually get wrong. And that's why people like us or people like me, if for example I'm poor in language especially in English, I will find an alternative language which will help me to work. And not only in mathematics even in the other subjects.

R: Any contribution you would like to put to my work?

S13: {Laughs} I would just say that what you are doing is the right thing about the language. If in future this research could be given that chance, I could say that the learning system or the way we usually set exam could be set in another way that would look friendly to the students and also the learners.

R: If given a chance to do what? If the research is given a chance to … ?

S13: To succeed.

R: Thank you so much I really appreciate your contribution and your time as well.

S13: Thank you very much.

End of reflective interview

APPENDIX J: SOLUTION TO THE TASK

a) Let the numbe of ~~row~~ original rows be x and let the numbe of original chairs per row be y.

Then $xy = 600$ - (i)

$\Rightarrow \quad y = \frac{600}{x}$ - - (ii)

After rearrangement.

$(x+5)(y-6) = 600$ - (iii)

$xy - 6x + 5y - 30 = 600$ - (iv)

Substituting for y in (ii) into equation (iv)

$x\left(\frac{600}{x}\right) - 6x + 5\left(\frac{600}{x}\right) - 30 = 600$

$600 - 6x + \frac{300}{x} - 30 = 600$

Simplifying and solving for x;

$-6x^2 - 30x + 300 = 0$

$x^2 + 5x - 3000 = 0$

$x = \frac{-5 \pm \sqrt{(5)^2 - (4 \times 1 \times -500)}}{2 \times 1}$

$= \frac{-5 \pm \sqrt{2025}}{2}$

$= +20$ or -25

$\therefore$ The original number of rows is $\underline{\underline{20}}$ Ans

(b) After re-arrangement

No of rows $= 20+5 = 25$

No of empty chairs $= 600 - 450 = 150$

$\Rightarrow$ No of empty chairs per row $= \frac{150}{25}$

$= 6$ Ans

APPENDIX K: SAMPLE OF STUDENTS' WORKSHEET

58

Let Number of rows be a b4 rearrangement.

After rearrangement N^o of rows

$= a+5$

Number of chairs $= n$

After Re-arrangement N^o of chairs

$= n-6$

$\frac{600}{a} = n$ (i)

$\frac{600}{a+5} = n-6$ (ii)

$600 = an$

$a = \frac{600}{n}$

Sub in (ii)

$\frac{600}{\frac{600}{n}+5} = n-6$

$600 = (n-6)\left(\frac{600}{n}+5\right)$

$600 = \frac{600}{n}(n-6) + 5(n-6)$

$600 = 600 - \frac{3600}{n} + 5n - 30$

$600 - 600 + 30 = 5n - \frac{3600}{n}$

$n(30) = \left(5n - \frac{3600}{n}\right)n$

$30n = 5n^2 - 3600$

$\frac{5n^2}{5} - \frac{30n}{5} - \frac{3600}{5} = \frac{0}{5}$

$n^2 - 6n - 720 = 0$

$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\frac{6 \pm \sqrt{36 - 4(-720)}}{2}$

$\frac{6 \pm \sqrt{2916}}{2}$

$\frac{6 \pm 54}{2}$ $\quad \frac{6+54}{2} = \frac{60}{2} = 30$

$n = 30$

Number of Rows.

$\frac{600}{30} = a$

$a = 20$

N^o of rows $= 20$.

$a+5$

$= 20+5$

$= 25$

Number of chairs

$= 30-6$

$= 24$

$\frac{450}{25}$ is

18.

$24-15$

$= 6$

53

Total number of chairs = 600.
Let the original number of rows = $\underline{x}$.
New number of rows = $x+5$.

$$\left(\frac{600}{x}\right) \qquad \frac{600}{x+5}$$

$$\frac{600}{x+5} - \frac{600}{x} = 6.$$

$$\cancel{x}(x+5)\frac{600}{\cancel{x}} - \frac{600}{\cancel{x+5}}x(\cancel{x+5}) = \frac{6}{1} \cdot x(x+5).$$

$$600(x+5) - 600x = 6(x^2+5x).$$

$$600x + 3000 - 600x = 6x^2 + 30x.$$

$$6x^2 + 30x - 3000 = 0.$$

$$x^2 + 5x - 500 = 0.$$

$a = 1$
$b = 5$
$c = -500$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

$$x = \frac{-5 \pm \sqrt{(5)^2 - (4 \times 1 \times -500)}}{2 \times 1}$$

$$\frac{-5 \pm \sqrt{25 + 2000}}{2}$$

$$x = \frac{-5 \pm \sqrt{2025}}{2}$$

$$x = \frac{-5 \pm 45}{2}.$$

$$x = \frac{-5+45}{2} \text{ or } \frac{-5-45}{2}.$$

$$x = \frac{40}{2} \text{ or } -\frac{50}{2}.$$

$\underline{x+5}$

No of row of the rectangle $20+5 = 25$.

No of chairs remaining $= 600-450$

$= 150$.

Each row $= \frac{150}{25}$

$= \underline{6}$ Chairs per row.

S13

Let the no of row $x + 5$

Let the noo of chair be $y - 6$

$x \times y = 600$ $\quad y = \frac{600}{x}$

$600 = (x+5)(y-6)$

$xy - 6x + 5y - 30 = 600$

$\cancel{x}\left(\frac{600}{\cancel{x}}\right) - 6x + 5\left(\frac{600}{x}\right) - 30 = 600$

$\frac{600}{1} - \frac{6x}{1} + \frac{3000}{x} - \frac{30}{1} = 600$

$\frac{600x - 6x^2 + 3000 = 600x}{x}$

$\frac{6x^2}{x} = \frac{3000}{x}$

$\cancel{x}\left(\frac{600}{\cancel{x}}\right) - 6x + 5\left(\frac{600}{x}\right) - 30 = 600$

$600 - 6x - \frac{3000}{x} - 30 = 600$

$\frac{600x - 6x^2 - 3000 - 30x = 600x}{x}$

$+6x^2 + 30x \pm 3000 = 0$

$6x^2 + 30x + 3000 = 0$

$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$X = -30 \pm \sqrt{30^2 - 4 \times 6 \times 3000}$

Let row be $x+5$ (original) No of chair in each row $= y$.

$x \times y = 600$ $\quad x = \frac{600}{y}$. $\qquad x+y = 600$.

$\frac{600}{\text{no of row}} =$

$\frac{600}{x+5} = \frac{y-6}{1}$

$\frac{600}{x+5} = \frac{600/y - 6}{1}$

$\frac{600}{\frac{600}{y}+5} = y-6$

$\frac{600}{x+5} = \frac{y-6}{1}$.

$xy - 6x + 5y - 30 = 600$

$600 - 6x + 5\left(\frac{600}{x}\right) - 30 = 600$

$-6x + \frac{3000}{x} - 30 = 0$

$-6x^2 + 3000 - 30x = 0$

$6x^2 + 30x - 3000 = 0$

$$\frac{-30 \pm \sqrt{30^2 - 6 \times -3000 \times 4}}{2 \times 6}.$$

New row $20+5$ 25

New chair $= 30-6$. 24

$x = \frac{-30 \pm 270}{12}$

$\frac{240}{12} = 20$

$600 - 150$

$600 - 450 = 150$ empty $x = 20$

Let K

$y = \frac{600}{x} = \frac{600}{20} = 30$

$\frac{150}{25} = 6$ $\qquad y = 30$.

$K = 6$

(i)

600 chairs = rows ↑ (a+5) ↖ 510

(6) (b-6) = cha

$600 \quad \frac{n!}{(n-r)!r!} \quad ax^2+bx+c$

600 chairs = (a+5) ~~b~~ rows

original number of rows a.

original no. of chairs in each row. b

$ab = 600 \quad a = \frac{600}{b} \quad (a+5)(b-6) = 600$

$(a+5)(b-6) = 600 \quad 5b-6b \quad ab-b-30 = 600$

$(a+5)(b-6) = ab \quad a = \frac{600}{b} \quad ab-b-630 = 0$

$ab-b=630$

$\cancel{ab+4}$ $\cancel{a}b-b-30=\cancel{a}b$

$b \left(\frac{600}{b} - b = 630\right)$

$-b = 30$

$(a+5)(b-6) = 600$

$600 - b^2 = 630b$

$b^2 + 630b - 600 = .$

$ab-b-30 = 600$

$\boxed{ab-b-630=0} \quad 600-630 = -30$

$\cancel{b(a-1)=630}$

$b(a \cdot \quad \frac{600}{b} b - b - 630 = 0$

$600 - b - 630 = 0$

$-b - 30 = 0$

$(a+5)(b-6)$

$\cancel{a}b - b - 30 = \cancel{a}b$

$-b = 30$

$ab = 600 \quad 5b-6b \quad a = \frac{600}{b}$

$(a+5)(b-6) = 600$

$ab-b-30 = 600$

$\cancel{600-b-30=600}$

$-b-570 = 600 \quad a = \frac{600}{b}$

$-b$

$ab-b-30=600$

$\frac{600}{b}b - b - 30 = 600$

$600-b-30=600$

$570-b=600$

$\boxed{-b=30}$

b	a	35
30	20	
35	24	

②

rows a . Chairs b ab $ab = 600$

$a = \frac{600}{b}$

$a \times b = 600$

$(a+5)$ - rows

$(b-6)$ - chair

$(a+5)(b-6) = ab$

$ab + 5b - 6a - 30 = ab$

$\frac{600}{b} \cdot b + 5b - 6 \times \frac{600}{b} - 30 = ab$

~~$600 + 5b - 600 - 30 = ab$~~

$\frac{600}{b} \cdot b + 5b - 6 \times \frac{600}{b} - 30 = \frac{600}{b} \times b$

$600 + 5b - \frac{3600}{b} - 30 = 600$

$b\left(5b - \frac{3600}{b} - 30 = 0\right) b$

$5b^2 - 3600 - 30b = 0$

$\frac{5b^2 - 30b - 3600 = 0}{5}$

$b^2 - 6b - 720 = 0$

$a = 1$

$b = -6$

$c = -720$

$b = \frac{6 \pm \sqrt{-6^2 - (4 \times 1 \times -720)}}{2 \times 1}$

$b = \frac{6 \pm \sqrt{36 + 2880}}{2}$

$b = \frac{6 \pm 54}{2}$

$b = \frac{6+54}{2}$ or $b = \frac{6-54}{2}$

$b = 30$

$a \times b = 600$

$a \times 30 = 600$

$a = \frac{600}{30}$

$a = 20$

$\Rightarrow (a+5)$ - rows &

$(b-6)$ Chairs in each row

$(20+5) = 25$

$(b-6) = 30 - 6 = 24$

$\frac{600}{450}$

$$\begin{array}{r} 600 \\ -\ 450 \\ \hline 150 \end{array}$$

$\Rightarrow$ 150 empty Chairs.

rows $= 25$

$\frac{150}{25} = 6$

$\frac{150}{25} = 6$

[redacted] S4

$C = 600$

x = No of rows — (iv)

No of chairs per row $= \dfrac{600}{x}$ — (i)

A

Now no of rows $= 5 + x$ — (ii)

No of chair per row $= \dfrac{600}{5+x}$ — (iii) $= \dfrac{600}{x} - 6$

B

Total no of chairs = No of row x chairs per row

$$\cancel{x \times \frac{600}{x} = (5+x) \times \frac{600}{5+x}}$$

$$\cancel{600 = 5^2 + x(5+x) + 600^2}$$

$$5+x \times \frac{600}{5+x} = \left(\frac{600}{x} - 6\right) 5+x$$

$\cancel{600} =$

$$\frac{600}{5+x} = \frac{600}{x} - 6$$

$$x\left(6 + \frac{600}{5+x}\right) = \left(\frac{600}{\cancel{x}}\right) \cancel{x}$$

$$6x + \frac{600x}{5+x} = 600$$

$$\cancel{5+x} \times \frac{600x}{\cancel{5+x}} = (600 - 6x) \times 5+x$$

$$\cancel{600x = 3000x - 30x^2}$$

$$\cancel{30x^2 - 300x + 60}$$

$$600x = 3000 - 30x + 600x - 6x^2$$

$6t^2 + 30t - 3000 = 0$

$0 = 3000 - 30t - 6t^2$

$t = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$t = \dfrac{-30 \pm \sqrt{30^2 - 4 \times 6 \times 3000}}{2 \times 6}$

$\dfrac{-30 \pm \sqrt{900 - 72{,}000}}{12}$

$\dfrac{-30 \pm \sqrt{-71{,}100}}{12}$

$\dfrac{-30 \pm \sqrt{71{,}000\,(i)^2}}{12}$

$\dfrac{-30 \pm 830\, i^2}{12}$

900

$64 \quad \dfrac{24_3}{72}$

72,000

$\cancel{30}^2$

case ⓐ

$\dfrac{-30 + 830}{12} \quad \dfrac{i^2}{12}$

$\dfrac{\cancel{800}}{\cancel{12}} + \dfrac{i^2}{12}$

$t = \left(\dfrac{200}{3} + \dfrac{i^2}{12}\right)$

case b

$\dfrac{-30 - 830\, i^2}{12}$

$\dfrac{-\cancel{860}}{\cancel{12}} + \dfrac{i^2}{12}$

$\left(\dfrac{-215}{3} + \dfrac{i^2}{12}\right)$

$600 - 450 = \underline{150}$

$$\left(\frac{200}{3} \quad \frac{+ -1^2}{12}\right)$$

$$\frac{200}{3} + \frac{-1}{12}$$

$$\frac{800 - 1}{12}$$

$$= \frac{799}{12} + 5$$

$$\frac{799 + 60}{12}$$

$\frac{859}{12}$ No. of row

$$\frac{150}{\frac{859}{12}}$$

$$\begin{array}{r} 15 \\ 12 \\ \hline 30 \\ 15 \\ \hline 180 \end{array}$$

$$150 \times \frac{12}{859} \qquad \frac{1800}{859}$$

$2.097 \simeq 2$ chairs per row.

S14

Let the no of rows be r $\quad r+5$.
$c \quad c-6$.

$c(c-6) = 600$.

$c^2 - 6c = 600$.

$c^2 - 6c - 600 = 0$.

$ax^2 + bx + c = 0$.

$a = 1$, $b = -6$ and $c = -600$

Part with error

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-(-6) \pm \sqrt{(-6)^2 - 4 \times 1 \times 600}}{2 \times 1}$$

$$= \frac{6 \pm \sqrt{36 + 2400}}{2}$$

$$= \frac{6 \pm \sqrt{2436}}{2}.$$

$$X = \frac{6 + \sqrt{2436}}{2} \text{ or } X = \frac{6 - \sqrt{2436}}{2}.$$

$$X = \frac{6 + 49.36}{2} \text{ or } X = \frac{6 - 49.36}{2}.$$

$x = 3 + 24.68$ or $X = 3 - 24.68$

$X = \underline{27.68}$ or $X = \underline{-21.68}$

$\underline{27}$

Total chairs = 600.

original row $\frac{r}{c} \quad \frac{r+5}{c-6}$.

each row = $\frac{600}{r}$ chairs

$\frac{600}{r+5}$ chairs

$$r(r+5)\left(\frac{600}{r}\right) - r(r+5)\left(\frac{600}{r+5}\right) = \left(\frac{6}{1}\right) r(r+5)$$

$600(r+5) - 600r = 6(r^2 + 5r)$.

$$\frac{6r^2}{6} + \frac{30r}{6} - \frac{3000}{6} = 0$$

$r^2 + 5r - 500 = 0$.

$ax^2 + bx + c = 0$,

$a = 1$, $b = 5$ and $c = -500$.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-5 \pm \sqrt{5^2 - 4 \times 1 \times -500}}{2 \times 1}$$

$$= \frac{-5 \pm \sqrt{25 + 2000}}{2}$$

$$x = \frac{-5 + \sqrt{2025}}{2} \quad \text{or} \quad x = \frac{-5 - \sqrt{2025}}{2}.$$

$$x = \frac{-5 + 45}{2} \quad \text{or} \quad x = \frac{-5 - 45}{2}$$

$x = 20$ or $x = -25$

$r + 5$ rows

Let no of empty chair in each row be c

$c(r+5) \qquad r(c-6) = 450$

$c(20+5)$

$25c$

25×6

$= 25 \times 6$

150 empty

No. of chairs occupied by 450 $= 600 - 25c$

$600 - 25c = 450$

$600 - 450 = 150$

$\frac{150}{25} = \frac{25c}{25}$

$c = 6$