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Mathematics lessons in a government secondary school in rural Rwanda:
A case study

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Abstract

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MATHEMATICS LESSONS IN A GOVERNMENT SECONDARY SCHOOL IN RURAL RWANDA:

A CASE STUDY

by Rachel Kate Ann Bowden

Language of instruction (LOI) is a major factor undermining educational quality and equity for millions of children studying through an additional language (L2) in low- and middle-income countries (The World Bank, 2021). In Rwanda, English medium instruction (EMI) is mandatory from primary to tertiary education and is associated with low learning outcomes, especially for marginalised learners (Milligan, 2020). Most research and advocacy around LOI to date has focused on the use of learners' home/community language/s (L1) at primary school, although secondary level is part of basic education in Rwanda and internationally. Given EMI is likely to remain at secondary level, it is important to understand *how* L2-medium instruction occurs in classrooms and how it can be strengthened (Milligan & Tikly, 2016). This critical and ethnographic case study explores mathematics lessons in a government secondary school in rural Rwanda and provides detailed description of situated pedagogical resources and constraints in order to inform teacher CPD in Rwanda and comparable contexts. The study centres on mathematics lessons, because competence in mathematics is key to the Rwandan national development vision, whilst examination results and the numbers of students who pursue science and mathematics streams at upper secondary are disappointing (Uworwabayeho, 2009). Data include 13 hours of lessons, recorded over a 5-month period; post-lesson interviews with the teacher and students; teacher and student interviews and focus groups; and a period of participant observation at school. Analysis centres on classroom discourse, and its relationship to discourses at school and in wider society. The study indicates considerable pedagogical resources in this classroom. The teacher constructs lessons with clearly defined pedagogical purpose, through routines and by responding to students, and using multilingual and multimodal semiotic resources to enable students to access English and mathematics. Students participate multilingually and multimodally to co-construct and at times lead classroom interactions. Monoglossic ideology constrains classroom communication, and the teacher's ability to adequately describe his practice. English is the language of mathematics, authority and visibility in these lessons; reinforcing linguistic hierarchy between European and indigenous African languages. The teacher does not consider himself a language teacher and while he uses a range of language supportive strategies, he does not discuss them in detail. The teacher and students describe students' English as 'lacking', and this undermines student confidence and verbal participation in lessons. The teacher mediates the 'English-only' textbook for students, and systematically omits talk-based tasks. I conclude that teacher CPD should recognise teachers' situated and subject-specific pedagogy as a resource to develop, rather than a problem to replace, and address linguistic ideology through building teachers' understanding of, and their ability to describe and develop their multilingual pedagogy and students' full linguistic repertoires.

Table of Contents

Table of Tables

Table of Figures

Research Thesis: Declaration of Authorship

I, RACHEL KATE ANN BOWDEN declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Mathematics lessons in a government secondary school in rural Rwanda:
A case study

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. none of this work has been published before submission.

RACHEL KATE ANN BOWDEN

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Abbreviations

ELP	Ethnography of Language Policy
EMI	English Medium Instruction
CBC	Competence-Based Curriculum
CCP	Child-Centred Pedagogy (see also LCE and LCP)
CDA	Critical Discourse Analysis
CoP	Community of Practice
CPD	Continuous Professional Development
CR	Critical Realism
CRB	Criminal Record Bureau
CS	Code-Switching
DfID	Department for International Development (UK)
DRC	Democratic Republic of Congo
EAC	East African Community
FDE	Further Diploma in Education
GDP	Gross Domestic Product
GPE	Global Partnerships for Education
ICT	Information Communication Technology
ID	Identification (as in ID cards)
L1	A person's main language/s (local/familiar/main)
L2	Additional languages learnt at school (former colonial/international/European)
LCE	Learner Centred Education (see also CCP and LCP)
LCP	Learner Centred Pedagogy (see also LCE and CCP)

Abbreviations

LOI	Language of Instruction
LOLT	Language of Learning and Teaching
LP	Language Policy
LPP	Legitimate Peripheral Participation
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Economy and Finance
MINEDUC	Ministry of Education
MOI	Medium of Instruction
NGO	Non-Governmental Organisation
NQT	Newly-Qualified Teacher
PIS	Participant Information Sheet
PISA	Program for International Student Assessment
REB	Rwanda Education Board
RENCP	Rwandan Education NGO Coordination Platform
RPF	Rwandan Patriotic Front
SA	South Africa
SSA	Sub-Saharan Africa
TDM TWG	Teacher Development and Management Technical Working Group
TLM	Teaching and Learning Material
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Children’s Fund
URCE	University of Rwanda College of Education
USA	United States of America

USAID	US Agency for International Development
VSO	Voluntary Services Overseas
12YBE	Twelve Years' Basic Education

Transcript key

…..	Pause. Each dot is equivalent to one second.
italics	Spoken quietly and not audible to the class
Public talk	Spoken at a volume intended to be audible to the class
LOUD	Spoken loudly, 'raised voice'
(*italics*)	Translation from Kinyarwanda to English
?	Rising intonation

Chapter 1 Introduction

1.1 Research focus

This thesis presents a case study of mathematics lessons in a government secondary school in rural Rwanda. The study combines ethnographic and critical approaches to explore how one teacher constructs and how learners participate in lessons, and how English medium instruction (EMI) and the competence -based curriculum (CBC) are constructed as part of lessons. The aim of this study is to provide practical recommendations to inform teacher education and continuous professional development (CPD) in Rwanda and comparable contexts, that enables teachers to develop their pedagogy, and mitigates the negative impacts of EMI on classroom communication.

The majority of research and advocacy around language of instruction (LOI) to date has concentrated on early years and primary education, in recognition of the importance of familiar language to initial literacy and foundational learning (Alidou et al., 2006; Laitin et al., 2019; Ouane & Glanz, 2011; Pinnock & Vijayakumar, 2009). The implications of LOI at secondary level are relatively under explored (Barrett & Bainton, 2016). This is an urgent area to address, given the low numbers of students who attend and complete secondary education although it is part of basic education (UNESCO, 2016) and the distinct LOI issues at secondary level. Secondary curricula typically contain more distinct subjects than primary (e.g., biology, physics and chemistry at secondary, instead of general science at primary), and subject-specific language (e.g., terms/concepts, spoken and written 'texts') increasingly abstract and distinct from 'everyday' communication (Polias, 2016). Mathematics is key to Rwanda's national development vision of becoming a hub for science, technology, ICT and entrepreneurship (MINECOFIN, 2000). However, examination results and the numbers of students who opt to study business and science streams at upper-secondary are disappointingly low (Uworwabayeho, 2009). Marginalised, multilingual students do less well in mathematics than their monolingual peers, and this suggests that LOI is a key factor in mathematics achievement (Moschkovich, 2002). The role of verbal language in mathematics is contested. On one hand, academics suggest that 'talking mathematically' is central to teaching and learning mathematics (Setati et al., 2008). On the other, Rwandan Policy makers assert that language is not that important for mathematics, and introduced EMI for maths and science before other subjects (Pearson, 2014). Recent research suggests multilingual students can be supported to learn mathematical language through participation in classroom-mathematical practice using their full linguistic repertoires (Moschkovich, 2015). There is a need to learn from multilingual mathematics teachers and students in EMI contexts, in order to inform efforts to enable teaching and learning.

1.2 Research rationale and audience

There is a 'learning crisis' in Sub-Saharan Africa, where gains in school enrolment have failed to translate into learning outcomes for millions of learners (The World Bank, 2018). Language of instruction (LOI) is understood to be a central factor undermining the education of an estimated 370 million children in low- and middle-income countries (LMICs), who learn through an additional language at school (Milligan et al., 2020; The World Bank, 2021). The use of an additional language (L2) as a medium for subject teaching in basic education in under-resourced, post-colonial contexts is associated with severe negative impacts on educational quality and equity (Milligan et al., 2020). Compared with education through a familiar language (L1), L2 medium education reduces the years children spend at school, and their likelihood of reaching secondary education (Seid, 2016). It leads to lower learning outcomes for the L2, and across the curriculum (Laitin et al., 2019; Ramachandran, 2017; Seid, 2019). Moreover, the negative impacts are disproportionately felt by students who are already marginalised, through poverty, rurality, ethnicity, gender and disability (Milligan et al., 2020). In Rwanda, levels of literacy and numeracy are alarmingly low and only a third students reach secondary level despite high enrolment at primary school (NISR, 2017). English is the official medium of instruction from the beginning of primary school through tertiary education, although the use of English is extremely limited outside of urban centres (Pearson, 2014; Williams, 2016). The policy favours the Rwandan elite who have historically had greater access to English and French, whilst additionally disadvantaging the majority, marginalised population (Spowage, 2018). In Rwanda, as elsewhere, English Medium Instruction (EMI) is associated with a complex of international, national and local forces and likely to remain in place. Therefore, there is a need to move beyond policy-level debates to look practically at how to mitigate the negative impacts of EMI, and this depends upon a detailed understanding of how EMI operates as part of classroom communication (Milligan & Tikly, 2016)

As Trudell (2016) points out 'the problem' with EMI is not multilingualism, or multilingual education per se, but the 'monoglossic ideology' associated with EMI across postcolonial contexts. Multilingualism is the norm for the vast majority of the world's population, and is associated with cognitive, social, personal, academic and professional benefits (Herzog-Punzenberger et al., 2017). Large-scale, longitudinal studies consistently show that additive multilingual education, where the use and development of learners' full linguistic resource is systematically supported, leads to higher levels of learning in the target language than learning language as a subject alone, and at-grade level achievement across the curriculum, with no additional negative impact for marginalised students (Collier & Thomas, 2017; Genesee, 2013; May, 2017). A number of factors combine to explain the stark differences in outcomes of EMI in under-resourced and post-colonial settings, and other forms of MLE in distinct contexts. These include stressful living and working conditions for teachers and students, and associated physical and mental health problems; large class sizes, a lack of teaching and learning materials and equipment, and limited access to running water and electricity; and scarce resources for academic literacy out of school, such as books, technology, museums etc. (Milligan et al., 2020). Sociolinguistic factors include the historical association between privileged elites and international languages, which mean that marginalised students suffer a 'double disadvantage' (Kerfoot & Simon-Vandenberg, 2015) through L2-medium education, in relation to their better-off peers. A further factor, is the linguistic distance between European and African languages, which makes it more challenging for speakers of indigenous African language to acquire English than for speakers of most other European languages (Milligan et al., 2020).

Perhaps the most significant factor undermining education through EMI is 'monoglossic ideology', which pervades diverse aspects of education systems, and undermines fundamental processes and resources. I use the term 'ideology' to refer ideas (in this case, about language, multilingualism and language learning) which are inaccurate and serve to promote particular political interests (Fairclough, 2013) (3.2.2). Monoglossic ideology includes the beliefs that languages exist as standard, closed systems of vocabulary, grammar, pronunciation and writing; that 'full' proficiency in a single language is the norm; and that 'languages' should be kept separate socially and psychologically (Blommaert, 2010). This ideology, which emerged as part of European nation-building was spread through colonisation when education of a select-elite through the medium of European language led to socio-linguistic inequalities which persist today (Milligan, 2020; Probyn, 2021). Colonial and postcolonial associations with English have been overlaid in recent years by globalisation discourses, which position competence in English as necessary for economic development and social mobility (Probyn, 2021; Tollefson & Tsui, 2018). Across the African continent, elites opt for education in European languages, perpetuating the association between European language medium education and socio-economic opportunity (Brock-Utne, 2017).

Monoglossic ideology is associated with 'subtractive' EMI, where English is seen to 'replace' learners' main languages at school, and learners' main languages are officially 'removed' past the point of transition. This has a drastic impact on learning, which is undermined when learners are not able to use the language and knowledge they have in the process (Bialystok, 2001; Cummins, 2017). In Rwanda, monoglossic ideology can be seen in textbooks, which are written as if for monolingual English users (Milligan et al., 2016). It is evident in examinations, where learners are assessed across subjects in English, and therefore "denied the opportunity to show what they know" (Rea-Dickins et al., 2013, p. 135). It also permeates teacher education, undermining teachers' own participation and learning, and inadequately preparing teachers to deal with the multilingual resources and language learning needs of their students (The World Bank, 2021).

Classroom communication in Rwanda and across SSA is multilingual, as teachers negotiate official language policy and the need for students to participate and learn (Heugh et al., 2017; Pearson, 2014; Williams, 2016). This indicates the agency teachers have to implement language policy in the classroom (Hornberger & Johnson, 2007). At the same time, classroom communication is constrained by monoglossic ideology. Teachers report feeling that they are denying students access to English by using their main languages, and regret contradicting official policy (Probyn, 2009; Webb & Webb, 2008). Teachers who recognise the pedagogical value of using L1, hide the practice because it is perceived negatively by others at school and in the local community (Early & Norton, 2014). Even when national policy promotes the use of familiar language in education, this is resisted by teachers, school leaders and local communities (Bunyi & Schroeder, 2017; Trudell, 2016). For example, Probyn (2021) reports that South Africa's additive multilingual education policy, in place since the mid-1990's has been consistently interpreted as 'English only' from year 4 primary onwards, in schools.

Recent initiatives aim to support secondary school subject teachers to develop their multilingual pedagogy in ways which support the learning of English, and EMI subject learning. For example, the Language Supportive Textbooks and Teaching project (LSTT) in Rwanda and Tanzania, developed pedagogical strategies for EMI subject instruction at secondary level, premised on "(...) the strategic use of Kiswahili to develop conceptual understanding and knowledge of English for academic purposes" (William & Ndabakurane, 2017, p. 101). Opanga, Uworwabayeho, Nsengimana, Minani, & Nsengimana (2021) found that biology lessons delivered by teachers using language supportive pedagogy increased student interactions and led to gains in content learning. The language supportive textbooks developed by the project include simple vocabulary and sentences, extensive visuals and English-Kiswahili glossaries. Activities support content and language knowledge and skills and promote the use of Kiswahili for pair and group discussions, and English for presentations and writing (William & Ndabakurane, 2017). This work is important, given that the impact of textbooks on learning outcomes is weaker with marginalised students, indicating that the language of textbooks may be a barrier to access (Milligan et al., 2019). Students report being better able to use language supportive textbooks at school, and receiving increased parental involvement with school learning at home (Clegg & Milligan, 2021). A number of African researchers utilise the model of 'pedagogical translanguaging', as a means to strengthen EMI -subject teaching and learning at secondary level. For instance, Makalela (2019) describes the work of the Hub for Multilingual Education and Literacies in South Africa (HUMEL) which teachers with theoretical sessions about translanguaging and supports their development of teaching and learning materials and model lessons. Reports from these initiatives indicate the potential of teacher CPD, and teaching and learning resources, to develop teachers' positive attitudes towards multilingual communication, their use of strategic classroom approaches and their critical awareness of linguistic hierarchies (Barrett et al., 2021; Makalela, 2019).

However, language policy researchers and advocates may fail to appreciate the complexity of competing concerns which teachers negotiate at school, in relation to their distinct subjects (Jaspers, 2018). Language supportive textbooks reflect learner-centred approaches from the competence-based curricula in Rwandan and Tanzania, prioritising, for example, student informal talk in groups as the basis for units of subject-learning (Barrett et al., 2021; Opanga & Nsengimana, 2021; REB, 2015). 'Pedagogical translanguaging' is aimed at developing students' biliteracy through EMI subject lessons, using 'learner-centred' approaches such as exploratory talk in groups (Banda, 2018; Charamba, 2020; Makalela, 2019; Probyn, 2019). There are sound pedagogical and political justifications for these approaches, but the practicality is questionable given failures to implement learner centred education in SSA (Guthrie, 2018; Msimanga, 2021). One reason for this is that 'pedagogical mode' (i.e., teacher-centred/performance mode or learner-centred/competence-mode) is intertwined with the material and social context of schools (Bernstein, 1996). Performance-mode pedagogy is associated with defined subject syllabuses and timetables, high stakes examinations, large class sizes, limited teaching and learning materials and long working hours for teachers (Barrett, 2007; Guthrie, 2018b). Widely cited pedagogical ideals, such as 'exploratory talk' in pairs and groups as a basis for learning, reflect research conducted in well-resourced Anglo-American contexts (Barnes, 1992; Gibbons, 2006; Mercer, 1995). Efforts to transfer these models to classrooms in SSA have been largely unsuccessful (Guthrie, 2018; Msimanga, 2021; Schweisfurth, 2015). Beneath the level of pedagogical mode, teacher and student interactions are unpredictable and may vary in the extent to which they enable students to understand and participate in classroom-subject discourse (Barrett, 2007; Lattimer, 2015). Given that EMI policy is likely to remain in place at secondary level, there is a need to enable teachers to develop their pedagogy, in ways which recognise, draw on and address contextual resources and constraints (Barrett, 2007; Milligan & Tikly, 2016; O'Sullivan, 2004).

1.3 Research questions

This study is informed by critical realism (3.2.1), and the view of mathematics lessons as agentively constructed by the teacher in particular material, institutional and social context and in ways which (re)produce and/or transform underlying social structures. Three main research questions guide this investigation:

1. How does this teacher construct these mathematics lessons?
2. How do students participate in these mathematics lessons?
3. How are English Medium Instruction and the Competence-based curriculum constructed in these mathematics lessons?

Question one reflects the recognition that, as instances of social reality, lessons are constructed by teachers and students in interaction, whilst teachers have considerably more power in the process (Guthrie, 2018). Classroom interaction matters greatly, as students' primary experience of education and access to the curriculum, an opportunity to learn subject specific knowledge, attitudes and practices, and gain the academic qualifications which may allow them to access future socio-economic opportunity. Through classroom interaction students also experience the 'hidden curriculum': entrenched social norms and assumptions present within institutions such as schools and in wider society that may be perpetuated and/or transformed in interaction. Classroom interaction is inherently unpredictable, because of the complexity of social systems and the agency of teachers and learners, and therefore necessitates ethnographic exploration of social practice combined with theory driven analysis of the connection between distinct social processes and relationships (3.2.1, 3.2.2). The second research question reflects a view of learning mathematics as participation in classroom-mathematical practice (Lave & Wenger, 1991; Moschkovich, 2002; Moschkovich, 2015; Vygotsky, 1978). This question directs attention to the practices which students participate in (and therefore the knowledge, skills and attitudes they potentially acquire), the 'language' that students use to participate, and the ways in which participation is enabled by the teacher. The third research question examines the construction of English Medium Instruction (EMI) and the competence-based curriculum (CBC) in lessons. This reflects my understanding of policy as constructed by people, as part of social practice (Hornberger & Johnson, 2007; Tollefson & Pérez-Milans, 2018) and my interest in how these two, apparently divergent policies are negotiated as part of practice.

1.4 My position as researcher

Research is inevitably subjective, as researchers decide what to investigate and how, based on what they understand the phenomena under investigation to be (ontology) and how it can be investigated (epistemology). It is therefore important for researchers to be reflexive about their position in relation to the phenomena they are investigating and their process of knowledge construction (Blommaert & Dong, 2010). Further, postcolonialism, which I understand as the cultural, political and economic arrangements associated with European colonialism in former colonised and colonising countries, and the ways that these events are described and interpreted

(Tikly, 1999, p. 605), is central to the phenomena I investigate, my position in this study and my process of knowledge construction. The Rwandan education system, including EMI and the mathematics curriculum are related to postcolonial processes and relationships which serve to perpetuate social inequalities within Rwanda and between Rwanda and other nation-states. I am a white, European researcher investigating classroom practice in a black Rwandan school, and employing black Rwandan researchers to collect and translate data and these relationships reflect, and to some extent reproduce, wider social patterns of inequality. The academic disciplines within which I conduct this study (sociology, linguistics, education), and the theories I draw on have been developed in the colonial/post-colonial world order, which has historically marginalised non-European ways of knowing. In order to mitigate the negative aspects of postcolonialism in this study, I have chosen to combine a critical analysis, with an ethnographic approach which prioritises the experiences and perspectives of research participants and allows me to identify and critique the functioning of colonial-era ideology. I reject essentialist categories, such as language, ethnicity and identity, which are associated with European modernity and colonialism (Tikly, 2016). I question discourses which position African teachers and learners as lacking in relation to linguistic and pedagogical 'ideals' developed in distinct contexts (chapter 4). I have also acted to mitigate the unequal relationship between myself, the teacher and students and local researchers (5.3, 5.4)

Next, I clarify the experiences which led to begin this PhD, and the beliefs and concerns which I brought to the task, to make my position in the study more transparent. From 2003, I worked as a teacher and senior teacher in Malaysia, Sri Lanka and Nepal. I was involved with teacher training and management for British Council teachers, and course design and teacher training for national teachers of English in Sri Lanka, Bhutan, Nepal and India. In this time, I began to question the value of training national teachers in generic communicative language teaching approaches, prompted by conversations with course participants who raised concerns about applying activities in their classrooms. I had the opportunity to act on these concerns when, in 2011, I began work as a project manager on a nation-wide English teacher development project in Malaysia. Funded by the Malaysian Ministry of education, and implemented in the East-Malaysia states of Sabah and Sarawak by the British Council, the project aimed to develop the English language proficiency and pedagogical skills of Malaysian primary school English language teachers. As part of a small management team, we designed a program based on our experience and understanding of how to support teachers to develop their practice in a sustainable way (Bowden, 2014, 2015). The project began with a period of participatory research, in which mentors were asked to get to know school communities, and work with teachers and other school staff to learn about classroom practice and identify priorities for development. Teachers were positioned at the centre of development activities, including investigating and developing their practice and to sharing their experiences with colleagues. As part of my role, I managed up to 23 mentors working in over 100 schools over a wide geographical area. I worked with Malaysian teachers, school leaders, and district state and national education officials. I experienced the education system across levels and saw how various aspects of the system, including our project and related policies among numerous other concerns, were constructed by teachers in different schools and classrooms. During the three years I worked on the project, I completed an MSc in Education, which was an impetus to develop my conceptual understanding alongside my work. In particular, I was struck by Alexander's book 'culture and pedagogy' (2001), which demonstrated the need to distinguish between pedagogical methods, and underlying pedagogical principles and theories. I returned to Europe, after over 10 years in Asia, with a small son and partner and have, since then, been based in Germany.

From 2016 until 2018 I was employed by UNESCO East Africa, to assist the Rwanda Education Board (REB) unit for Teacher Development and Management and the Teacher Development and Management Technical Working Group (TDM TWG) to create a 'national teacher development framework' (Appendix A). The assignment unfolded over several stages: an initial situation analysis; consultation workshops to review findings and generate recommendations for the framework; and drafting the final document. The purpose of the framework was to coordinate teacher development and management in schools, sectors, districts and nation-wide; at different stages of teachers' careers; and across government and non-government actors. The task was to communicate the changes laid out in policy, and provide additional guidance to support teacher development and management in schools. Ultimately the framework centred around a series of 'teacher competences', arranged under three over-arching categories: teacher attitudes, knowledge and skills. For each competence, there were four performance levels mapped to the four career stages defined in the Rwandan teacher statutes (Official Gazette n° 48 of 28/11/2016): pre-service, newly qualified, serving and expert-teacher. The framework contained guidance for school-based teacher development, for example, how teachers and teacher-mentors could use the teacher competences to identify strengths and areas for development and plan, do and review development activities at school. The teacher competences were intended to inform the planning of pre-service and in-service CPD, and increase coordination between different providers, such as teacher training colleges, the University of Rwanda, the Rwanda education Board, NGOs and faith-based organisations. They were also intended to allow REB to monitor the impact of teacher CPD on classroom practice and to support school-based management of teachers. They contained guidance for school-based appraisal, including lesson observation, interviewing teachers and teacher development portfolios.

Writing the teacher competences was challenging. I saw the need for greater clarity about 'quality' teaching and learning, in the light of the new curriculum, and to coordinate teacher CPD between agencies and at different levels of the education system. At the same time, I was concerned that the pedagogical 'ideals' of the new curriculum and language in education policy were distant from what was happening, or feasible in classrooms. At national level, EMI was interpreted into coursebooks and teacher CPD programs as 'English-only', but the lessons I observed in schools and colleges were multilingual. It seemed vital not to restrict this 'natural' and evidently often effective, use of teachers and students' multilingual repertoires. During the situation analysis, I found that the CBC was often interpreted as 'groupwork', while, with the exception of a 'model' CBC lesson which I observed in a teacher training college, the lessons I observed were teacher-led and highly structured. Nevertheless, there were clear differences in student engagement between lessons. It seemed unfair and unhelpful to presume that current teaching was a problem which needed to change, or that introducing groupwork and increasing the amount of English used in lessons would necessarily benefit students. Indeed, it seemed that these pedagogical and linguistic ideals reflected distant and distinct classroom contexts. In the end, I based the competences on Antoniou and Kyriakides (2013) 'teaching factors' that impact students learning, but which don't reflect a single pattern of classroom organisation. However, the model made no reference to multilingual teaching and learning. In the document, recommended the term 'familiar language' along with 'medium of instruction', to validate the use of Kinyarwanda alongside English in the teacher competences (Appendix A, p.12).

This experience led me to see the need for better understanding of 'situated' classroom practices in Rwanda, and comparable low-resource and multilingual contexts, to inform teacher CPD and other interventions aimed at supporting teaching and learning. My glimpse of the complex conditions in which teachers work led me to question the relevance and feasibility of the CBC and EMI, as portrayed in coursebooks and national CPD programs. I was sure there was much to learn from current teaching, based on my experience working with teachers in Malaysia, and what I had seen in Rwandan classrooms and heard from teachers and students.

1.5 Thesis outline

This thesis is divided into ten chapters. In this first chapter, I present the research focus and aim, the rationale for the research and research questions. I discuss how my professional experience and my work as a consultant to the Rwanda Education Board led me to conduct this study. In Chapter 2, I provide an overview of Rwandan history with a focus on how language and education have featured in, and been used by distinct socio-political regimes over time. I describe the current education system, and the policies of English medium instruction (EMI) and the competence-based curriculum (CBC). In Chapter 3, I present the theoretical framework for this study which includes concepts from a range of disciplines. In Chapter 4, I review a selection of studies relevant to the present investigation. I point to the approaches and insights on which this study builds, and the gaps which it addresses. In Chapter 5, I describe the research design, and methods for data collection and analysis. In Chapter 6, I present my findings to the first research question: how does this teacher construct mathematics lessons? I demonstrate the purposeful way in which this teacher constructs lessons, using multilingual and multimodal semiotic resources, in ways which are routine and responsive to students. In Chapter 7, I present findings and analysis for the second research question: how do these students participate in lessons? I show that students participate in lessons using a range of multilingual and multimodal semiotic resources, to co-construct and at times lead lesson activities and interaction, in ways that are more and less controlled by the teacher. In Chapter 8, I present findings around how the curriculum and language in education policies are constructed as part of classroom practice. I portray the ways in which students are active and help each other in these lessons; and how English is used as a language of mathematics and visibility. In Chapter 9, I discuss the findings of this investigation in relation to recent research and consider the extent to which my analysis builds on or challenges the work of others. Finally, in Chapter 10, I highlight how the findings of this study connect with and contribute to academic understanding, and make recommendations for teacher CPD and research in Rwanda and comparable contexts. I outline the limitations of the study, and reflect on what I have learnt in the process of conducting this investigation.

Chapter 2 Context

2.1 Introduction

In this chapter, I provide a historical overview of the Rwandan education system, including gains made since 2000 and some of the challenges facing teachers and students in government schools today. I discuss the origins and appeal of English medium instruction (EMI) and the competence-based curriculum (CBC), and their dominance of national teacher CPD. The account of context provided in this chapter informs my analysis of lessons, and is intended to inform the application of the findings to other contexts. The chapter is divided into three main sections. In section 2.2, I present a historical review from the period preceding colonial invasion, with a focus on how language and education have featured in, and been used by, different socio-political orders. In section 2.3, I discuss the current government and education system, looking at achievements and challenges. In sections 2.3.1 and 2.3.2 I turn to two dominant education policies: English medium Instruction (EMI) and the competence-based curriculum (CBC). I discuss the emergence of these policies and what is known about how they impact teachers, learners and teacher CPD.

2.2 Historical overview

There is evidence of three distinct socio-economic communities, which inhabited and moved across the territory now known as Rwanda, from 10,000 BCE onwards: hunter-gatherers, cattle traders and settlers (Gaugler, 2013) (see *Figure 1*, below). The territory was organised into a number of small kingdoms, comprised of clans and led by chiefs, which were eventually replaced by a single kingdom around 1500BC. Members of all three socio-economic groups shared territory and membership of political units (ibid.). It seems reasonable to assume a high degree of mutual intelligibility within and between people and groups, in Kinyarwanda, understood as ‘the language spoken in Rwanda’ (ibid).

Figure 1 Political map of Rwanda

The period of colonial occupation in Rwanda lasted from around 1890 until 1962, firstly with German (1890-1916) followed by Belgian rule (1916-1962). This period began with the signing of the Berlin treaty in 1884, although German colonisers delayed several years before approaching Rwanda (Mamdani, 2002). The German administration ruled indirectly, using the existing socio-political order as a means to mobilise a workforce and extract resources in the interests of the colonisers (ibid.). They distinguished between three ethnic groups, Tutsi, Hutu and Twa, which, in line with the racist ideology of the day, were deemed biologically distinct but in practice were defined by occupation, wealth and power (ibid.). To administer indirect rule, the Germans used 'Tutsi', defined as people already relatively high up in the socio-political order, as administrators. The Germans claimed that Tutsi were foreigners to Rwanda and of superior intelligence to other Rwandans, and use this claim to justify their differential treatment of supposedly distinct ethnic groups (ibid.). The distinction between the three ethnic groups that the Germans introduced, the different treatment they received, and the power each group had, forged rifts between these communities which were to deepen over time with disastrous impacts (ibid.). German language was not introduced to Rwandans, because of the German policy of indirect rule. Some schools were started in the era, initially by missionaries, to teach religious texts (Hoben, 1989).

The Belgians were awarded the colony of Rwanda by the league of Nations, as part of war reparations after the first world war. They used the administrative infrastructure established by the Germans for indirect rule, whilst also introducing their own forms of direct administration. The Belgians continued to employ the ethnic categories introduced by the Germans, including the idea that Tutsi were foreign. Racial categories were formally used in the 1934 census. These were further reified in the ID cards which all Rwandans were obliged to carry after 1935 (Mamdani, 2002; Williams, 2016). The Belgians expanded the education system with the aim of generating manpower for the colonial administration, educating predominantly Tutsi people. Thus, the pattern of socio-economic and political advantage for Tutsi was continued, alongside the idea that they were foreign to Rwanda. People defined as Hutu suffered extreme brutality at the hands of the colonisers during this period, and large numbers fled to neighbouring territories. Political organisation of Hutu increased in the 1950s (ibid.). French was the medium of instruction in schools from the fourth grade of primary school onwards, and became associated with social and economic opportunity (Pearson, 2014). Formal education became increasingly necessary for business and employment during the colonial era (des Forges & Newbury, 2011). Indeed, unequal access to education was a major factor driving the pre-independence revolutionary movement (Prunier, 1995).

Rwanda gained independence from Belgium in 1962, when a radical Hutu government took power. The new government continued the system of ID cards for Rwandans as part of a program of positive discrimination, which aimed to redress historical disadvantage, for example, by reserving places in education for Hutu people (Williams, 2016). These reforms were presented as a means to counter discriminatory colonial policy, but were in effect an extension of discrimination (Prunier, 1995). The system was used to deny Tutsi voting rights, based on the claim that they were foreign, and to prevent Tutsi from registering at schools. While positive discrimination succeeded in increasing the numbers of Hutu in education, it was more difficult to access work, where established social networks were less amenable to government control. The continued use of ID cards, and the discourse of Tutsi's being foreign fuelled inter-ethnic tensions, and instances of extreme violence. As a result, large numbers of Tutsi were forced to flee to neighbouring countries where Tutsi militia were formed (Williams, 2016).

The emphasis of education shifted dramatically post-independence. Rwanda's first constitution mandated primary education to be both free and compulsory. In the colonial era, education had been for the select few and limited based on the requirements of the administration. Post-independence, education was positioned as a mechanism for national development through the education of the general population. Between 1973 and 1990, Primary education enrolment increased from 46% to 65% but transition to secondary remained extremely low (9.2%) (ibid.). The continued use of ID cards in this period may have been used to restrict access to secondary school on ethnic lines (ibid.). The 1962 Constitution of the Rwandan Republic awarded Kinyarwanda the status of national and official language, and French that of an official language. Similar to other post-colonial nation states, the former colonial language, French, was retained as an official language and used in education, government and business and Kinyarwanda was enshrined as the national language (Pearson, 2014).

The second Rwandan republic, led by Juvenal Habyarimana, lasted from 1973 until the genocide of 1994. There was surface adoption of democracy, although in practice the regime was authoritarian. Habyarimana was elected with 98% of the vote, in elections that were apparently rigged (Williams, 2016). Under Habyarimana, efforts were made to foster reconciliation between the two main ethnic groups. The foreign status of Tutsi was officially rescinded and they were recognised as a Rwandan ethnic minority. 1973 saw the massacre of Tutsi in neighbouring Burundi and the formation of the RPF and other radical Tutsi liberation groups is said to date from this period. In 1979, a general reform or “Rwandazation” was launched (Hoben, 1989, p. 17). The Ministry of Education extended free and compulsory primary education from six to eight years and instated Kinyarwanda as the medium of instruction for all eight years (Rosendal, 2009). The policy did not last long, however. In 1991, French was re-introduced as the medium of instruction from the fourth year of primary onwards. The official reason given was the low results in national French language examinations but may have been related to the economic downturn which occurred in the period (Pearson, 2014). As a result, Kinyarwanda medium education may have become associated with economic stagnation. The economic downtown affected the whole region and led to increased social unrest. This put an end to reconciliation efforts in Rwanda, and claims that Tutsi’s were foreigners began to resurface (Mamdani, 2002). Instances of inter-ethnic violence between Hutu and Tutsi in Burundi and Uganda increased, which further exacerbated the radicalisation of people from both groups. The French government supplied weapons and materials to the Hutu majority government and militia (ibid). By early 1993, 15% of population were internally displaced and the civilian population were increasingly armed (ibid).

The Rwandan genocide was triggered by events on the 6 April, 1994, when President Habyarimana's plane was shot down and the Prime Minister, was killed. In three months of violence that followed, an estimated 800,000 Tutsi and moderate Hutus were murdered. In July that year, RPF occupied Kigali and in the weeks which followed an estimated two million Hutus fled to the neighbouring Democratic Republic of Congo (DRC). RPF militia followed, and allegedly carried out mass killings. Violence in the region of Kivu is ongoing, and considered a major cause of unrest in DRC (Mamdani, 2002). During the genocide the majority of school buildings were destroyed. Tutsi teachers and students were targeted as they were associated with an educated elite (Obura, 2003). Approximately 75% of all public servants, including teachers were either killed, fled or went missing (Williams, 2016).

2.3 The current government and education system

In 1994, the Government of National Unity was established with a power sharing agreement between President Bizimungu, and vice-president Paul Kagame. In 2000, Bizimungu resigned and Kagame took sole power and has been President of Rwanda ever since. Kagame is a controversial figure. On one hand, since 2003 Rwanda has a constitution and regular elections are held. In the past twenty years of rule, reports of armed conflict in Rwanda have been limited. GDP has risen steadily along with progress against internationally recognised development indicators. Education is a prime example, with 2016 figures indicating net enrolment of 97% and gross enrolment of 140%, a figure which is explained by the large number of children and young people going back to school (NISR, 2017). On the other hand, critics question Rwanda's democratic status, citing electoral irregularities, the suppression of opposition and dissent in Rwanda and overseas, and constitutional reforms which make it possible for Kagame to serve several consecutive terms (Reyntjens, 2016; Samuelson, 2012; Samuelson & Freedman, 2010). Moreover, while conflict within national boundaries has been limited in this time, Rwanda has been involved in regional conflicts. For example, in 2009, Rwanda staged a joint military operation with the national army of Democratic Republic of Congo (DRC), targeted at Hutu extremists. There are reported to be 80,000 Rwandan refugees in the DRC, and 70,000 in Burundi (CIA, 2021). The fact that a number of Rwandans have been granted asylum since 1998 is an indication that human rights abuses continue (ibid).

Despite these concerns, the Rwandan government enjoys support in Rwanda, in the region and internationally (Williams, 2016). The political legitimacy of the current government rests in large part on their demonstration of "development gains"; a means of securing support nationally, and political and economic alliances regionally and internationally (Williams, 2016, p. 551). Education is a "development good" highly valued by Rwandans and this has fuelled a series of large-scale educational reforms over the past 20 years (ibid.). The 2003 constitution mandated compulsory basic education, which meant six years of primary school, free of cost. The policy was realised through 'capitation grants', where payments per student were made directly to schools. Although the system did not entirely remove costs for students and their families, it was credited with a rapid increase in enrolment (Williams et al., 2014). At this point, enrolment in secondary school remained low, due to fees and the fact that enrolment in secondary education depended on performance in national end of primary examinations (Williams, 2016). This changed in 2010, when the policy of Nine-Year Basic Education was introduced meaning that the first three years of secondary school were included as basic education. Fees were removed from public schools, and promotion to lower-secondary was automatic rather than determined by exam results (ibid.). The following year Kagame included the promise of 12 years basic education in his re-election campaign, and won the election with a landslide victory. The policy was put in place shortly after (Pearson, 2014).

Increased access to education has proved popular with the electorate and been welcomed by the international development community (Williams, 2016). However, while increasing access is a pre-requisite for quality, it raises particular challenges for teaching and learning (Tikly & Barrett, 2013). For instance, in response to the rapid rise in student enrolment, primary schools in Rwanda operate double-shift patterns, doubling many teachers' workloads (Williams, 2016), and recruiting and retaining sufficient teachers to keep up with the rise in student numbers has proved challenging (UNESCO & MINEDUC, 2015). There are, in addition, steep inequalities between schools. So-called '12YBE' secondary schools accept students regardless of exam results, and are seen as "lesser" schools, and schools "for those who have failed" despite the number of students who have performed well in exams, and attend because they cannot afford to attend more prestigious schools (Williams, 2019, p. 649). Negative attitudes towards these schools and the students who attend them, coupled with large numbers of high needs students and limited teaching and learning resources, means they confer limited value in terms of skills, social capital, and status compared with other schools (ibid.).

Research on learning outcomes indicates there is cause for concern about educational quality. For instance, in one study, on average, students could only identify 36.7% of the letters in their alphabet after one year of primary school (Friedlander, Gasana, & Goldenberg, 2014). A USAID (2014) study found that about 60% of Primary 1 students, 33% of Primary 2 students, and 21% of Primary 3 students were unable to read a single word of a grade-appropriate passage. In mathematics, 59% of Primary 1 students could not solve any subtraction problems and 41% could not solve any addition problems. In Primary 3, about one in ten scored zero on addition tests. Repetition and dropout rates are persistently high (NISR, 2017). In primary school, the highest dropout figures are consistently recorded as occurring between primary 5 and 6 (ibid.), suggesting that exams are 'pushing students out' of schools who publish exam results (Williams, 2016). Moreover, while exam grades are not a requirement for 12YBE schools, other schools use results to select students and some students choose not to attend school at all rather than attend 12YBE schools (Williams, 2019). Statistics from 2016 show that of the Rwandan young people who could be at secondary school, only 32.9% enrol (NISR, 2017, p. 52). In 2016, just over 135,000 students were enrolled in Senior 1 and 67,000 in Senior 6. The largest drop, of 31%, is between students in Senior 2 and Senior 3 when students sit national O-level examinations. Teachers also suffer economic hardships. Teachers I spoke to during the situation analysis cited low salary as a reason to move out of teaching, and for primary teachers to become secondary school teachers, who are better paid. Several teachers reported working alongside teaching to supplement their incomes, and a senior REB staff member told me that rural placements were popular as they enable teachers to grow their own food.

The political structure of education in Rwanda, both nationally and transnationally, raises particular concerns with regards to educational quality. Rwanda operates a policy of decentralisation, alluded to in Vision 2020 and formally defined in the Education Sector Strategic Plan (MINEDUC, 2013). The policy is promoted as a means of “empowering the population to participate in development activities that have an influence them, including education” (MINEDUC, 2013, p. 33). However, decision-making power remains in the hands of central government, leading Chemouni (2014) to propose the term “de-concentration” instead of decentralisation. Williams (2016, p. 553) defines power in terms of inner and outer circles. The inner circle includes the office of the President, the Cabinet, the Minster of Education (MINEDUC), Ministry of Finance (MINECOFIN), the Ministry of Local Government (MINALOC), and the UK’s Department for International Development (DFID). The outer circle consists of the Rwanda Education Board (REB), Parliament, the United States Agency for International Development (USAID), UNICEF, and the consortium of NGOs called the Rwandan Education NGO Coordination Platform (RENCP). Schweisfurth (2006), discusses the influx of Anglophone educational concepts and discourses resulting from the governments’ geo-political move away from France, in addition the returning diaspora from neighbouring East African countries. As she points out, nations which are dependent on international aid are susceptible to international education discourse and this can draw attention away from local contextual realities and concerns (ibid.).

Williams (2016), notes that the Office of the President has special powers to establish the priorities of the education sector. This has proved problematic, to the extent that decisions have been politically motivated, rather than targeted at educational improvement. Decisions such as the expansion of basic education to 12 years, mandated school feeding and the policy of English as Medium of Instruction (EMI) are reported to have come directly from the Office of the President. These decisions have appeared outside of Education Sector Strategic Plans, and in some ways work against longer term policy planning (ibid.). For example, moves to increase educational quality through reducing teacher working hours and class sizes were put on hold with the advent of 12 years basic education, the suddenness of mandatory school feeding led to costs being initially borne by students (ibid.). EMI has led to national CPD programmes which focus on training teachers in English (ibid) (Pearson, 2014). The “de-concentrated” model of administration has been highly effective in increasing student enrolment and rebuilding schools (Chemouni, 2014). However, top-down and centralised reforms may be less suited to improving classroom teaching and learning (ibid.).

2.3.1 English Medium Instruction

At the time of this study, Rwanda’s language in education policy was to use English as a medium of instruction from the fourth year of primary onwards[1]. For the first three years of primary, students learnt through Kinyarwanda with English as a subject. From the fourth year of primary school onwards, Kinyarwanda is ‘removed’ and English becomes the medium of instruction (Pearson, 2014). English was first introduced as an official language in Rwanda, alongside Kinyarwanda and French, following the genocide, as a means to facilitate the re-integration of Rwandan diaspora returning from Anglophone countries in the region (Steflja, 2012). In 1996, MINEDUC announced that English was to be used alongside French in schools as an official instructional medium, and schools opted either for French or English (Pearson, 2014). Then, in 2008, a decision, described as “sudden” and “unplanned”, was made to instate English as the sole medium of instruction (Pearson, 2014, p. 44). On the 8 October 2008, the Rwandan Cabinet issued a resolution for EMI “(…) in all public and Government-sponsored primary and secondary schools and higher learning institutions” (Rosendal, 2009, p. 99). The policy was later adapted to allow for the use of Kinyarwanda for the first three years of primary, with English thereafter (Pearson, 2014).

Teachers describe the policy shift as “top-down and mandatory” (Pearson, 2014, p. 44), although schools had considerable autonomy to implement the policy, as there was little direct guidance from the government. As a result, forms of implementation differed between schools, and classrooms (ibid.). Pearson notes that teachers’ backgrounds were a significant factor determining how they implemented EMI in their classrooms (Pearson, 2014, pp. 48–49). In general, she found that teachers used English and Kinyarwanda in class, to enable students to access language and content, a finding which is echoed by Williams (Williams, 2016). In both studies teachers appear to feel they are transgressing the policy by using Kinyarwanda alongside English, whilst seeing this as a necessary pedagogical strategy (ibid.). Nevertheless, Pearson concludes that teachers are optimistic about their achievements under the policy, and positive about the future.

[1] Recent reports suggest the removal of Kinyarwanda as the medium of instruction in early primary, in favour of EMI for all grade and levels of education (Milligan, 2020).

A range of factors are associated with the shift from French to English, including the geo-political shift from Francophone toward Anglophone alliances in the East African region and internationally, post-genocide, and the popular appeal of English as a 'global language' (Milligan et al., 2016), and the need to accommodate returning diaspora (Steflja, 2012). EMI can be seen as a 'development good' provided by the government to the people as a means of shoring up political legitimacy (Williams, 2016). Samuelson and Freedman (2010) and Samuelson (2012) claim that EMI is a sign of victory from the RPF to the general population, and a means to secure the socio-political advantage of the ruling elite. The range and complexity of these factors suggest that EMI is likely to remain in Rwanda (Milligan et al., 2016).

The use of European languages as an official medium of instruction is a common practice in post-colonial countries (Tollefson & Tsui, 2018), and is staunchly criticised in academic circles (Alidou et al., 2006; Milligan et al., 2020; Ouane & Glanz, 2011) . The consensus among academics is that learning English for three years as a subject is not sufficient for learning through the language thereafter, and many teachers lack the language skills for teaching (Milligan et al., 2016; Schroeder et al., 2021). EMI is associated with numerous practical problems, due to the distance between the 'monolingual' linguistic ideology of the policy, and the multilingual reality of classrooms and communities. For instance, Milligan, Clegg and Tikly (2016) found students were unable to access the content of mathematics and science textbooks, which are written as if for monolingual speakers of English. A further concern, is the way that EMI has dominated national teacher CPD in Rwanda. As a result of the policy, capitation grants, intended for teacher development, were re-directed from schools to the Rwandan Education Board and used to finance national teacher development programs such as the school-based mentoring program, which aims to improve teachers English and pedagogy (REB, 2017; Williams, 2016). In practice, Williams reports, the focus has been on improving teachers' English proficiency, with the rationale that "to improve pedagogy, teachers must first be able to speak the language of instruction"(Williams, 2016, p. 556). The teachers in Pearson's study report that training was focused on basic language skills for a generic audience, and not of practical use for subject teachers of different levels (Pearson, 2014). It appears that, like coursebooks, teacher training programs reflect the ideology of the language policy, rather than multilingual classroom practices. As such, CPD may offer teachers scant opportunity to develop their practice, and may undermine teacher's confidence to use their multilingual repertoires to help students learn (Probyn, 2009).

2.3.2 The Competence-based Curriculum

The competence-based curriculum was introduced in Rwanda in 2015 (REB, 2015). Like EMI, the CBC seems to serve a range of interests, nationally and internationally. In national discourse, the curriculum is positioned by the government as part of the national development trajectory, laid out in the flagship document “Vision 2020”, to transform the country into a middle-income economy (MINECOFIN, 2000). As such, the ‘new’ curriculum can be understood as a means of delivering development to the Rwandan people (Williams, 2016), although the assumption that education leads to economic growth and social mobility is problematic (Alidou et al., 2006; Williams, 2019). The adoption of the new curriculum serves regional political and pragmatic purposes. In 2013, Rwanda signed The EAC Treaty, in which Articles 5 and 103 commit Partner States (Burundi, Kenya, Tanzania, Uganda and Rwanda) to align curricula, examinations and accreditation of education and training (REB, 2015). Further, the curriculum, along with other national economic and education policy, signals allegiance to an international socio-political order, where democracy and free-market economics are core values (Tabulawa, 2003) .

The CBC advocates ‘learner-centred’ pedagogy and can be understood as part of international trends in learner-centred education (LCE) policy (Schweisfurth, 2011; van de Kuilen et al., 2020). LCE is associated with economic, emancipatory and cognitive goals, and this has contributed to widespread acceptance in international and national education policy discourse (Schweisfurth, 2011, 2015). In Rwanda, the CBC is presented as part of a global trend aimed at preparing “for the competitive global economy” (REB, 2015, p. 3). The document also asserts that competence-based curricula lead to better learning outcomes, citing Japan’s performance in PISA 2012 as an example (REB, 2015, p. 4). Finally, as Van de Kuilen et. al. note (2020), co-operative and collaborative learning are associated with social stability and national unity; pertinent goals in Rwanda. The goals listed in the Rwandan curriculum framework, aligned with curricula in the East African Community, include:

- Patriotism, unity and harmony
- Good governance, democracy and respect for human rights
- Human resource for sustainable social and economic growth
- Life skills, religiousness and ethical values
- Culture, traditions and customs
- Sustainable development of the environment
- The use of scientific and technological innovations (REB, 2015, p. 11)

The list is ambitious and broad, and indicates the tendency of LCE proponents to focus more on the intended outcomes of LCE and competence-based curricula, and less on pedagogical process (Chisholme & Leyendecker, 2008), and the complex challenge facing schools and teachers. The challenge is arguably exacerbated by “silence” and “confusion” with regards to LCE pedagogical processes (Schweisfurth, 2015, p. 260). As Schweisfurth (2015) puts it:

> "(…) the lack of critical engagement with pedagogy at an international level has allowed that space to be filled with ready-made prescriptions from a range of agencies concerned with classroom practice in low-income countries" (Schweisfurth, 2015, p. 261).

These "prescriptions" are often drawn from western contexts (Tabulawa, 2003), and reflect discourses around competence-mode pedagogy (Bernstein, 1996) (3.3.2). In a recent study of 24 primary and secondary teachers' beliefs and classroom practices in Rwanda, van de Kuilen et al. found that:

> "In all but one class, teachers put children in groups. In fact, teachers seemed to equate LCP (leaner centred pedagogy) with group work" (van de Kuilen et al., 2020, p. 11)

This finding resonates with the situation analysis fieldwork I conducted in 2016 (1.4). Van de Kuilen and colleagues conclude that the use of 'group work' actually undermines learner participation, because of the large numbers of students and limited numbers of books in the lessons they observed.

The CBC is described as ushering in a new dawn of education in Rwanda (REB, 2015). Teacher CPD is seen as central to the successful implementation of the new curriculum, and 'learner centred pedagogy' is a central aim of national-scale teacher CPD as a central focus (REB, 2017). In "Vision 2020" the claim was made that 'quality':

> "(…) has been declining, due in a large part to low calibre teaching staff and therefore, the government will organise intensive teacher training programs" (MINECOFIN, 2000, p. 15)

While the tone of discussion about teachers and teaching has improved since then, the emphasis on training teachers in 'new' approaches, rather than learning from and supporting teachers to develop their situated pedagogies, suggests negative perceptions of teachers and teaching persist. Focussing teacher CPD in improving teachers' English proficiency and skills in learner centred pedagogy (REB, 2017) is problematic, given that effective CPD engages teachers in the process of learning and change based on their current beliefs and practices (Villegas-Reimers, 2003). It is perhaps 'doubly' problematic, given the limited practical feasibility of 'English only' and 'groupwork' in Rwandan classrooms (Milligan et al., 2016; van de Kuilen et al., 2020).

2.4 Chapter summary

In this chapter I provided a historical overview of education and language in education in Rwanda, where, since the colonial era, education in a European language has been associated with socio-economic opportunity (Mamdani, 2002). The substantial gains made in education since 2000 are accompanied by concerns about teaching and learning quality, in particular for ‘12 years basic education’ schools (Williams, 2019). The focus of the education sector is on increasing teaching and learning ‘quality’, and teacher CPD is a central strategy (REB, 2017; Williams, 2016). National-scale, centrally planned teacher CPD is focussed on improving teacher’s English proficiency and their skills in ‘learner centred pedagogy’ (ibid.). These pedagogical and linguistic ‘ideals’ are distant from classroom practice and may therefore fail to engage teachers in improving their classroom practice, and even undermine established and effective practices. Little *detail* is known about classroom practice in Rwandan secondary government rural schools, including but not limited to how teachers implement the CBC and EMI as part of their practice. Such detail is vital to inform teacher CPD that engages teachers in learning and developing their practice (ibid.), and to challenge ‘deficit’ discourses about teaching and learning in Rwanda and comparable contexts in education policy and research (Barrett, 2007; Brinkman, 2019; Lattimer, 2015; Schweisfurth et al., 2020).

Chapter 3 Conceptual framework

3.1 Introduction

In this chapter I present the theoretical and conceptual basis for the present investigation. I begin by situating this study in relation to other critical and ethnographic studies of multilingual classroom communication and language in education policy (Johnson, 2009; Martin-Jones, 2015). I go on to outline the philosophical basis of this study in critical realism (CR) (Archer, 1998; Bhaskar, 2008) and present key concepts from critical discourse analysis (CDA) (Fairclough, 2013) and the ethnography of communication (Gumperz, 1982; Hymes, 1972), which are used in this study. In the final section of the chapter, I present additional concepts, models and theories which are used to describe and analyse data: translanguaging (Garcia & Li, 2014), pedagogical modes (Bernstein, 1996), socio-cultural theory (Lave & Wenger, 1991; Vygotsky, 1978) and academic literacy in mathematics (Moschkovich, 2015). These are coherent with the critical and ethnographic focus and conceptual framework of the study, and were selected in interaction with the data, as having the best descriptive and explanatory potential, and potential for informing future recommendations.

3.2 A critical and ethnographic study of classroom communication

This investigation builds on critical and ethnographic studies of multilingual classroom communication and language in education policy, which investigate how social structures are reproduced and transformed as part of classroom communication, and the links between local classroom interactions, and institutional and wider social processes (Martin-Jones, 2015; Martin-Jones & da Costa-Cabral, 2018). This work has emerged from the field of language policy research, a field which has experienced dramatic epistemological and conceptual shifts since its inception in the 1960s, when western-educated researchers were engaged in the task of planning language policies for newly-independent post-colonial nations. In this first phase, termed ‘early language planning’ by Ricento (2000) and ‘neo-classical’ by Tollefson (1991) research was mainly aimed at informing top-down national-level language plans. Research was underpinned by positivist epistemology, including the belief that categories such as ‘language’, ‘dialect’ and ‘national identity’ had fixed meanings and clear boundaries and relationships and that it was possible to plan for, predict and control language use, through centrally designed plans and policies. Research methods in this period included large scale surveys of language attitudes, and quantitative analysis of such data with little or no reference to the social and political context of language use

(Martin-Jones & da Costa-Cabral, 2018). Linguistic diversity was seen as a problem to be managed, and minority languages were considered 'inefficient' (Johnson & Ricento, 2013). The 'diglossic' language policies which resulted defined distinct languages and contexts of use. Although language policy *research* has become considerably more nuanced since this early period, language planning in many postcolonial contexts continues to reflect (and reproduce) these early assumptions. Rwanda's language in education policy, which assigns English as the language of education and Kinyarwanda as a language of heritage and community, without any formal recognition of the socio-political implications of the policy, is a prime example.

A second phase of language policy research was influenced by post-structuralist, critical theorists such as Foucault (1971) and Bourdieu (1991) who highlighted the political dimension of language and language policy. Tollefson's 'historical structural approach' is recognised as initiating a major shift in language policy research, aiming "to examine the historical basis of policies and to make explicit the mechanisms by which policy decisions serve or undermine particular political and economic interests" (1991, p. 32). Tollefson focused on the ways in which ideology is used to normalise language practices in institutional settings, such as schools. Other critical language policy researchers investigated the role of English worldwide as a form of linguistic imperialism (Phillipson, 1992) and the use of language in education policy to promote the interests of minoritized social groups (Hornberger & King, 1996). However, critical language policy research was itself criticised for a narrow focus on national-level policy, and for top-down and deterministic assumptions about the functioning if ideology and power. For example, Ricento (2000) called for greater understanding of micro-level language policy, and the relationship between macro and micro levels.

The third phase of language policy research is described as 'critical-ethnographic' (Johnson, 2011, 2018) and aims to commensurate a critical focus on how language policy is used to perpetuate ideology and serve political interests, and a situated focus on how people "implement, interpret, and perhaps resist policy initiatives in varying and unique ways" (Hornberger & Johnson, 2007, p. 509). This work is a response to the critique that emphasis on the hegemonic power of national language policy obscures the agentive role of local educators, acting in diverse socio-linguistic settings. Critical ethnographic studies investigate:

> "(…) policy as a practice of power that operates at multiple intersecting levels: the micro-level of individuals in fact-to face interaction, the meso level of communities of practice and the macro-level of national states and larger global forces" (McCarty, 2011, p. 3)

Contemporary research focuses on the complex of multi-layer language policy processes, in a way which foregrounds the agency of people to interpret and appropriate policy, and the contextual constraints and resources they use. Researchers combine ethnographic approaches to gather rich and detailed information about language use, institutional context, and the perspectives of teachers and students and critical analysis to highlight the ways in which policy discourses constraint practice and possible alternatives (Martin-Jones, 2015). Ricento and Hornberger's onion model (1996) was influential in focusing attention on classroom interaction, and teachers as language policy agents operating at the core of the onion, within a layered 'ecosystem' of resources and constraints. In this seminal paper, the authors highlight important distinctions between language policy activity at national, institutional and classroom level. They note how attitudes towards languages and their speakers are deeply embedded in institutional structures and practices, which form a key mediational layer between national language in education policy and classroom practice. Teachers can both reproduce social and intuitional norms without realising it, and/or transform classroom communication and promote institutional and social change. Hornberger and Johnson (2007) ask researchers to 'slice the onion ethnographically' to illuminate local interpretation and implementation of language policy. Drawing on case studies of bilingual intercultural education in Bolivia and bilingual education in the school district of Philadelphia in the USA, the authors show how "ideological and implementational spaces" open and close, and reveal agentive spaces in which local actors implement, interpret and at times resist policy initiatives (2007, p. 507). Ramanathan (2005)shows how teachers in India use students' vernacular languages as pedagogical resources, even within restrictive official language policies and makes the case that situated realities should inform language policies rather than linguistic ideologies. Johnson (2009) addresses the need for conceptual and methodological clarity in language policy research, by combining critical discourse analysis of language policy, with ethnographic data from local contexts of language policy implementation in the School District of Philadelphia. Cincotta-Segi (2011b, 2011a) combines CDA and ethnographic research in her study of national language policy in Laos PDR, to illustrate how language policy is interpreted and appropriated at ministry, school and classroom level, and how language policy ideologies constrain classroom communication. Sah and Li (2018) present a critical, qualitative case study of how English medium is 'localized' in one under resourced, English medium public school in Nepal. Using Bourdieu's (1991) concept of linguistic capital, they highlight the distance between 'rosy perceptions' of EMI and the reality of classroom communication, where the status of minoritized languages in education was undermines and students suffer the 'double disadvantage' of not being proficient in English or Nepali. The authors conclude that EMI serves to reproduce linguistic marginalisation and educational inequality for children with low socio-economic status.

Researchers in this tradition see language and language policy as social practice, contingent on the wide socio-political context. As such, contemporary language policy studies are concerned with three intersecting dimensions: 1) the life trajectories of social actors and the linguistic and discursive resources they acquire through social interactions; 2) the culture and practices of specific language policy contexts e.g., classrooms, workplaces etc.; and 3) national and international ideologies, discourses and policies (Tollefson & Pérez-Milans, 2018, p. 8). The critical dimension of contemporary studies includes critiquing historical and contemporary 'techno-rational' approaches to language planning and highlighting the ways in which situated language practices, discourses and ideologies reproduce political inequalities with the goal of moving towards more equitable beliefs and practices (Martin-Jones & da Costa-Cabral, 2018).

As this overview indicates, there have been substantial conceptual and methodological developments in recent years, which address the central issue of how macro-level policies relate to micro-level interactions. Nevertheless, concerns remain about the weakness of the conceptual underpinnings of language policy research (Simpson, 2019). In the following sub-sections, I outline how I combine critical realism (CR), critical discourse analysis (CDA) and ethnography of communication to conceptualise the relationship between mathematics lessons and language in education policy in this study.

3.2.1 Critical realism

Critical realism (CR) is a movement in social science, which aims to develop a rigorous and systematic approach to the study of social phenomena. This meta-theoretical or philosophical position has much to offer the field of language policy research, as a way to theorise language and language policy in relation to wider social processes and relationships. CR was developed by Roy Bhaskar in the late 1970s, in order to move beyond positivist and interpretivist accounts of social reality, both of which he recognised limited. He critiqued positivists for applying the empirical methods from the natural sciences to the study of social reality, and therefore conflating what is, with what can be known (Bhaskar, 2008). Early language policy research (outlined above) is an example of the limitations of taking a positivist approach to social research. Interpretivists, on the other hand, are criticised for endorsing the relativist position that different ways of understanding social reality have equal value, and for inadequately theorising the material world as part of social reality. In response, Bhaskar (2008) presents a qualified, critical and non-reductionist naturalism, or 'transcendental realism' which distinguishes between the 'intransitive' dimension of being (ontology), and the 'transitive' dimension of knowing (epistemology). He suggests that social reality exists beyond individual acts of observation, but that knowledge of social reality is always partial and can never be fully known.

Social systems are understood as complex ‘open systems’, which makes social action and interaction inherently unpredictable and necessitates ethnographic research. In closed systems, objects operate in consistent and predictable ways, and causal laws can be derived from the empirical measurement of regularities. Social objects are also real, but constantly change, in a social world which is systemically open because it is peopled (Scott, 2010). Social systems are both intrinsically open, and extrinsically open. People have intrinsic properties and powers which makes their behaviour unpredictable, and this complexity expands extrinsically, as they interact in the material and social world (Archer, 1998). Scott and Bhaskar (2010) refer to the ‘powers’ of social objects, which may or may not be possessed, exercised or actualised as they interact in the social and material world. Possessed powers are inherent or intrinsic to social objects and may not be observed unless exercised or actualised. Exercised powers are triggered and have an impact on the social system, although this may still not be visible as they may be suppressed or counteracted by other processes. Actualised powers work with the social system (i.e., they are not suppressed or counteracted), and may or may not be visible. Powers can be possessed (but not exercised or actualised, and therefore invisible); possessed and exercised (but not actualised, and therefore visible or invisible); or possessed, exercised and actualised (and may be visible or invisible).

Bhaskar (2008) posits that there are three levels to social reality: the empirical, the actual and the real (Table 1, below) Of these, the empirical may or may not be directly observed. For example, the empirical level of ‘these mathematics lessons’ is partly captured through recorded audio and video data. The actual, is determined through micro-ethnographic analysis of the data, to answer the question ‘what is going on here?’ and to identify ‘speech events’ (3.2.3, below) with rules, roles and objectives in relation to which the empirical language data ‘exists’. The third level, ‘the real’, refers to the complex of social relations between this teacher and these students, the school, the education system, mathematics, the community, the government, the end of year examinations. This category includes broader social processes and objects, such as power, social class, postcolonialism and globalisation.

Level	**General example**	**Specific example**
The empirical	Language Speech acts The material environment	‘Who can come and try?’
The actual	Speech events	Bid to initiate

	Discourse	'demonstration'
The real	Social mechanisms, processes and relationships	Interacting relationships between: The teacher, students, school, education system, mathematics, CBC, EMI,

Table 1 Three levels of social reality

Critical realism is also instructive in conceptualising 'social structure' in a non-deterministic way, which accounts for the relationship between social structure and specific social interactions. Porpora (1998) describes social structures as 'systems of relationships among social positions', an interpretation of social structure which resonates with the Marxist focus on systems of production and social class but can include other systems of relationships such as colonialism and racism. Social structures are related to individual actions in complex ways, as described by Porpora:

> "The causal effect of the structure on the individual are manifested in certain structured interests, resources, powers, constraints and predicaments that are built into each position by a web of relationships. These comprise the material circumstances in which people must act and which motivates them to act in certain ways. As they do so, they alter the relationships that bind them in intended and unintended ways" (Porpora, 1998)

Social structures don't determine action, because people may fail to recognise their interests or choose to act against their interests. However, social structures exert influence on human actions because when people act against their interests as configured in the wider social order, they incur some form of cost (Porpora, 1998).

Ethnographic research is used to discover the unpredictable and creative ways which actors respond to their structured conditions. CR research focuses on the interplay between social structures and human agency, which are understood as a dialectic: social reality is constructed by people, acting in a pre-structured world with structural constraints and possibilities they did not produce. At the same time, social actors reproduce and transform the structures which they utilise and are constrained by in their activities. Thus, society is the condition and outcome of human agency, which reinforces and transforms society (Porpora, 1998).

In addition, theory has a central role in CR studies. That is because underlying structures and mechanisms which shape social reality are not directly visible, but may be inferred through systematic and theoretically informed analysis of empirical data (Bhaskar, 1998). Theory is tentatively 'tested' in relation to the data and emerging analysis. In the process, theories can be judged as more or less appropriate to the phenomena under investigation, and this can lead to the development of theory in ways which enable better understanding and better action. Critical realists recognise the political dimension to social interaction, and consider the illumination of underlying mechanisms which perpetuate social inequality as a means to make these processes amenable to change. Thus, CR is an attempt to reconcile ontological realism, epistemological relativism and judgemental rationality (Archer, 1998).

The CR position implies the need for rich and detailed data around situated social action and interaction as a basis for understanding how underlying mechanisms, processes and powers enable and constrain, and are reproduced and transformed in, social action. In addition, there is a need for theory to explain particular phenomena, which should be judged regarding its descriptive and explanatory power.

3.2.2 Critical discourse analysis

I have chosen to use aspects of Fairclough's critical discourse analysis (CDA) for this investigation, because of its alignment with CR and the usefulness of CDA concepts in relation to the phenomena I am investigating. Fairclough describes CDA as a dialectic-relational approach to studying language as social practice in relation to other social relationships and processes (Fairclough, 2013). The 'critical' objective of CDA, as defined by Fairclough, is to investigate how contemporary capitalism prevents, limits, and under certain conditions facilitates human well-being and flourishing in order to inform efforts to mitigate negative and enhance positive effects (Fairclough, 2013, p. 2). CDA has also been used in investigations of language policy, to explore processes of nationalism and racism in relation to classroom communication and education system texts and discourses (Cincotta-Segi, 2011b, 2011a; Johnson, 2009). Fairclough defines three core characteristics of CDA research:

1) systematic and 'transdisciplinary' analysis of discourse and other social processes;
2) analysis as well as detailed description; and
3) a critical stance, defining problems, resources and means of mitigating and enhancing these (Fairclough, 2013, p. 11)

CDA shares with CR a view of social reality as constructed by people, and the contingent and dialectical relationship between social conditions and social events (Fairclough, 2013, pp. 4–5). Like CR, Fairclough's CDA conceives social structures in terms of social relations between people and social and material objects and processes, such as power and institutions. Thus, CR and CDA retain a focus on the material world, and 'real' structures and processes distinct from human perceptions of social reality. Both also share a commitment to social improvement, through improved knowledge of the social world, and the theories used to describe and analyse social reality. Fairclough (2013, p. 7) distinguishes between negative critique, i.e., a focus on what is wrong and how wrongs might be righted or mitigated, and positive critique i.e., how people mitigate negative effects and how they can be further supported. The notion of 'positive critique' resonates with the emphasis on identifying opportunities for positive action in Johnson's (2009) ethnography of language policy, and enables me to make recommendations for teacher CPD, which build on teachers' situated practices based on my analysis in this study.

I also find Fairclough's distinction between 'language', discourse and ideology useful for my analysis, and now outline these concepts as presented by Fairclough and used in the present study. Fairclough (2013) uses the term "semiosis" to refer to language which people use to construct and participate in social events and texts, including verbal and non-verbal linguistic forms. For this investigation of multilingual classroom communication, I use the concept of 'translanguaging', which I outline in detail below. The term discourse can be used to denote a number of disparate meanings, including written or spoken 'texts', subject-specific terms and ways of communicating, and particular world-views or perspectives on reality e.g., neo-liberal, or feminist. I have come to see the value of distinguishing between language, discourse and ideology to allow for the analysis of separate elements and processes, and relationships between them. Discourses are semiotic ways of construing the world (Fairclough, 2013, p. 256). Discourse is understood as a complex and layered set of relations, between people in concrete communicative events, and more abstract 'discursive objects' such as languages, discourses and genres (see below) and objects that exist in the material world: people, power relations and institutions (Fairclough, 2013, p. 4). Fairclough draws on Foucault's 'orders of discourse' (1971) and this is consistent with the idea of indexicality (Blommaert, 2010) applied in contemporary language policy research. The notion of 'interdiscursivity' is central to analysis in CDA, to identify "which discourses, genres and styles are drawn into a text and how they are articulated together" (Fairclough, 2013, p. 7). As Fairclough states:

> "(…) discourse is shaped by structures, but also contributes to shaping and reshaping them, to reproducing and transforming them. The structures are most immediately of a discoursal/ideological nature- orders of discourse, codes and their elements such as vocabularies and their turn-taking conventions, but they also include in a mediated form political and economic structures, relationships in the market, gender relations, relations within the state and within institutions of society, such as education" (Fairclough, 2013, p. 59)

Fairclough defines ideology as a way of representing reality, which is found to be inaccurate (i.e., have weak explanatory value) and to function to maintain some form of power (2013, p. 9). He asserts that there is no single location for ideology which pervades social structures and processes, or 'orders of discourse' (Foucault, 1971) and speech events. The relationship between social structures and events is dialectical: ideology is reproduced and transformed as part of social action.

> "Ideology is located, then, both in the structures which constitute the outcomes of past events and the conditions for current events, and in events themselves as they reproduce and transform their conditioning structures" (Fairclough, 2013, p. 59)

I choose to distinguish ideology from discourse, whilst recognising that ideology and discourse are dialectically related. As Fairclough notes, ideologies operate across institutional boundaries and situations, and it is important to be able to investigate ideology as a distinct phenomenon.

3.2.3 Ethnography of communication

My conceptualisation and analysis of classroom interaction is informed by the foundational work of Dell Hymes (1972) and John Gumperz (1982) on the ethnography of communication and interactional sociolinguistics. Hymes and Gumperz were the first to challenge the 'objectivist' view of communities as constant and bounded entities with stable linguistic norms. Instead, informed by anthropology, they approached language as a social and cultural practice, and highlighted the ways in which linguistic practices are used to construct and negotiate social identities and relationships (Martin-Jones & da Costa-Cabral, 2018). This led to research which investigates human interactions and meaning making processes and paid attention to the institutional context of communication.

I apply three key concepts developed by Hymes and Gumperz in this study. These are, 'speech acts', 'speech events' and 'contextualisation cues'. Speech acts are utterances which occur in sequence and interaction between participants, and are a sub-unit of speech events. Hymes (1986) originally asserted that speech acts were verbal but later work has indicated the importance of non-verbal utterances, and utterances where verbal and non-verbal forms are integrated. Speech acts are notoriously hard to define, because they operate in relation to speech events and because not all utterances are fully expressed or experienced. 'Speech events' are units of norm-driven interaction, which are considered "the basic unit of analysis in speech communities" (Gumperz & Hymes, 1986, pp. 16–17). The meaning of social interaction can only be understood in relation to speech events, and speech events can be only be understood through analysis of interaction. As Gumperz states: "(…) The speech event is to the analysis of verbal interaction what the sentence is to grammar" (Gumperz & Hymes, 1986, pp. 16–17). Further, speech events are central to understanding wider social systems, as the mediating layer between social system and individual utterances. Hymes (1986) presented his SPEAKING model, for the analysis of speech events, with each letter representing a particular area of focus, i.e., Situation, Participants, Ends, Act sequence, Key, Instrumentalities, Norms, and Genres. Situation includes the physical location of the event (the setting) and the 'scenes' which occur there. For example, in the setting of a classroom likely scenes include lessons, exams, or break-time. In relation to participants, Hymes distinguishes between the speaker (who creates talk) and the addressor, who delivers talk as well as hearers or receivers. For 'ends' Hymes distinguishes between explicit objectives (e.g., today we are going to learn how to draw a frequency polygon) and goals, which may be implicit and not necessarily shared by participants. Act sequence, refers to the sequence of speech acts which make a speech event, and Hymes draws attention to the forms and situated meanings of specific acts within a sequence. Key refers to the tone or manner in which an act is performed. Instrumentalities refers to the 'channel' of communication (e.g., face to face, or remote) and the 'form of speech' includes 'language' (e.g., Kinyarwanda, English), dialect, codes and varieties. I address 'instrumentalities' further under translanguaging (below). By 'Norms' Hymes refers to 'norms of interaction', which are formal features such as turn-taking, and floor holding, as well as permissible topics and forms of speech associated with a particular speech event. 'Norms of interpretation' determine the interpretation of particular acts. The final category 'genre', can be used within a speech event or as an overarching category. For example, 'a lesson' which is comprised of speech events and acts, or 'telling someone off' which is a genre that may occur within different activities. In my analysis, I use the term 'activity' to refer to pedagogical speech events, a term which I take from Lemke's description of science lessons in the USA (1990).

A final central concept which I apply is Gumperz's notion of the 'contextualisation cue' (1982) Gumperz developed the concept as part of the approach he termed 'interactional sociolinguistics' developed through his research on cross-cultural communication. He used the term refer to the signals used by bilinguals to make situated inferences about what is going on, to signal the context for their own contributions, and to evaluate the contributions of others. Contextualisation cues cover a wide range of semiotic signals, including prosodic, phonological, grammatical, and lexical choices, different forms of code-switching, style-shifting, gaze, gesture and movement (Martin-Jones, 2015, p. 452). As such, contextualisation cues provide the key between here and now situated interaction and the social processes and relationships which are referenced (or indexed) to construct interactions. Contemporary researchers refer to 'socio-linguistic scales' and the "indexical" function of language in signalling these scales as part of situated interactions

(Blommaert, 2010). The concept of socio-linguistic scales resonates with Foucault's (1971) notion of 'orders of discourse', which is used in CDA (Fairclough, 2013) to identify 'interdiscursivity'.

The combination of critical and ethnographic perspectives has proved particularly valuable in illuminating the intrinsically unpredictable human dimension of social reality and drawing connections between social interaction and wider social structures and processes (Martin-Jones, 2015). In chapter 4, I review a number of critical ethnographic studies of classroom communication and language in education policy.

3.3 Language and pedagogy

As already indicated, language is central to this study in a number of ways. Language is a tool by which people signal to each other 'what is going on here?', as they construct communicative contexts, objectives and identities. Seen critically, language bridges between particular instances of interaction and wider socio-political processes and relationships:

> "Language is a material form of ideology, and language is enmeshed by ideology" (Fairclough, 2013, p. 59)

Language is the empirical basis for my research, the 'visible' (if never fully knowable) component of social reality, which I use to make inferences about actual and real social processes that are reproduced and transformed in classroom interaction (Bhaskar, 2008). In addition, I understand language to be central to pedagogical processes: to the construction of teaching and learning events or activities (Lemke, 1990), to the core pedagogical processes of classroom interaction. In this section, I present the concept of translanguaging which I utilise in recognition of the particularities of multilingual linguistic competence and communication (Garcia & Li, 2014), selected because it aligns well with the critical and ethnographic focus of the present study, and the multimodal nature of mathematics communication.

3.3.1 Translanguaging

The term translanguaging (trawsieithu, in Welsh) was first used to describe the pedagogical strategy of switching between English and Welsh for language reception and production tasks in Welsh schools (Baker, 2011). Perhaps the most well-known definition of translanguaging, was proposed by Garcia (2009, p. 45) as the "multiple discursive practices in which bilinguals engage in order to make sense of their bilingual worlds". Crucially, translanguaging reflects a view of the language practices of bilinguals:

> "Not as two autonomous language systems, as has traditionally been the case, but as one linguistic repertoire with features that have been societally constructed as belonging to two discrete languages" (Garcia & Li, 2014, p. 2)

Garcia (2009, p. 16) builds on Grosjean's (1989) analogy of the combined running and sprinting competences of a high-hurdler, which cannot be directly compared to either a runner or a sprinter by proposing that the competences should be considered part of a single system. She presents the analogy of an off-road vehicle to describe how multilinguals draw on verbal and non-verbal linguistic resources in relation to the socio-political contours of particular contexts and interactions. This notion of multilingual competence as a single, integrated system reflects the application of dynamic systems theory to explain the psycho-linguistic systems of multilinguals and connections between internal and social cognitive-ecosystems (Herdina & Jessner, 2002).

Garcia and Li (2014) cite a range of influences behind the concept, including Bakhtin's notion of heteroglossia, which posits that language is inextricable from the context of use, and is inevitably subjective and political as it used by people in ways which reflect their beliefs to achieve particular goals. In addition, they cite Chilean biologists Humberto Maturana and Francisco Varela, whose concept "autopoesis" refers to the close connection between the ways in which people perceive and act in the world. Recent theoretical work portrays translanguaging as "a fluid dynamic flow of meaning making" (Lin, 2019, p. 8). Lin suggests that instead of focusing on individual speakers and listeners using discrete languages "(...) it would be more productive to view them as co-ordinated parts of an assemblage of agents and resources" (ibid.). Makalela develops this unitary view of translanguaging for the African context, as part of "(...) the African value system of ubuntu where languages are interwoven in a system of infinite dependent relations that recognise no boundaries between them" (Makalela, 2019, p. 238).

There is an explicit, political dimension to translanguaging, as a movement which "(...) releases ways of speaking of subaltern groups that have been previously fixed within static language identities and are constrained by the modern/colonial world system (...)" (Garcia, 2013, p. 161). The ideological shift from languages as static entities to fluid repertoires positions multilingualism as the norm, not an exception in the "schooling ecosystem" (Makalela, 2019, p. 239). Translanguaging is not inevitably 'good' and is also prone to reproduce social hierarchy, as indicated in Sah and Li's (2020) study of translanguaging in Nepali classrooms. They found that the use of English and Nepali, the dominant international and national language, took precedence over the use of other local languages and reinforced social inequalities.

The concept of translanguaging has implications for language learning goals in multilingual education. Garcia (2009) and Garcia and Li (2014) critique the goal of parallel competence in two or more languages. They argue that, because language is learnt through participation in social practice, it is natural that different linguistic competences, including translanguaging and mono-languaging practices develop in relation to specific social practices and language registers. The notion of translanguaging also has important implications for research of multilingual communication, enabling researchers to focus on the communicative competence of participants rather than their 'partial' use of particular languages. Planas (2021) reflects on how her own understandings of language and mathematics have changed as a result of recent conceptual developments:

> "A generation of scholars (myself included) have walked a long journey to view languages, language use, and curricular content in the multilingual mathematics classroom beyond the countable alternation of separate languages. Still today, state policies, pedagogies, and ideologies of monolingual normativity narrow the lenses through which we think about mathematics teaching and learning, and what can comprise mathematically relevant language use in the distinct research contexts" (Planas, 2021, pp. 2–3)

The translanguaging position is compatible with CR and CDA on a number of levels. The theory of translanguaging locates linguistic communication as part of a dynamic psycho-linguistic system and social system (Garcia & Li, 2014; Herdina & Jessner, 2002). This aligns with the CR view of social systems as open, intrinsically and extrinsically (Archer, 1998). In addition, CR, CDA and translanguaging all recognise that power, social structures and relations and agency are central to communication. From the perspective of translanguaging, multilingual communication is inevitably enmeshed in systems of power which can be oppressive or liberating, depending on the positioning of speakers and their agency (Garcia & Li, 2014).

3.3.2 Pedagogical modes and qualities

Pedagogy is notoriously hard to define (Schweisfurth, 2015). The lack of detail surrounding what is meant by 'quality' pedagogy in international discourse is widely recognised (Alexander, 2007, 2015; Guthrie, 2018; Schweisfurth, 2015). Schweisfurth (2015, p. 261) suggests that the vacuum of understanding has been filled by 'ready-made prescriptions' provided to teachers by a range of agencies concerned with improving educational quality and equity. 'Learner-centred education' (LCE), a 'catch-all' term for educational quality, has been central to educational reform efforts in SSA for several decades accompanied by increasing concern of the failure of reforms to impact classroom teaching and learning (Chisholme & Leyendecker, 2008; Guthrie, 2018; Schweisfurth, 2011). Schweisfurth (2011, p. 425) conducted a meta-analysis of 72 studies reporting on LCE implementation in SSA, and concluded that the history of LCE "is riddled with stories of failure grand and small". More recently, Guthrie (2018) reviews 32 studies from statistically representative low-income countries to show that LCE reforms were inappropriate and/or had major implementational difficulties. There has been much debate as to the reasons for implementation failure. LCE is criticised as a "western import" aimed at securing geo-political advantage for Anglo-American nations (Schweisfurth, 2015, p. 262). Tabulawa (2003) asserts that LCE is aimed at ideological change as much as pedagogical improvement, and is best understood as a form of cultural imperialism. Guthrie (2018) concurs that LCE is a form of 'soft power' which is aimed at expanding the influence of progressive ideology, albeit often unwittingly by advocates of LCE on the ground. A central problem regarding LCE is the lack of conceptual clarity (Schweisfurth, 2015). For example, a wide-spread approximation for LCE, that is communicated to teachers internationally is 'groupwork' (Altinyelken, 2010; Schweisfurth, 2011; van de Kuilen et al., 2020). There is a tendency is to focus more on the social, economic and cognitive benefits of LCE than the pedagogical processes by which these are to be realised (Altinyelken, 2010; Chisholme & Leyendecker, 2008).

Various efforts have been made to address the silences and confusion regarding LCE pedagogies. Chisholme and Leyendecker (2008, p. 8) discuss the theoretical basis of LCE in constructivist pedagogy based on the key principle that knowledge is not transmitted, it is constructed in the mind of the learner. Learning is considered a mentally active process, resulting from personal interpretation of knowledge on the basis of prior knowledge and experiences. They note that prior knowledge and experiences are determined by culture and social context, and that language influences culture and thinking, and is central to learning and the development of higher cognitive processes. However, these theoretically grounded principles often appear one-sided: they fail to account for the role of the teacher, or subject and context specific practices. A further point of contention is the presumed link between LCE and educational quality, whether measured in terms of teaching and learning interactions (Alexander, 2001) or PISA scores (Schweisfurth, 2013). Alexander's (2001) cross-nation study of pedagogy in India, France, Russia, the UK, and the USA found no co-relation between what he termed "conceptualisation of curriculum" and worthwhile pedagogical interactions. He draws attention to examples of highly structured teacher-led whole class interaction where students are guided to express sophisticated ideas, and groupwork where students are off-task and de-motivated. Significantly, he concludes that there is no direct link between particular methods and 'quality', as he says:

> "(…) there is far more to pedagogy than making a simple choice between whole class teaching, group work and individual work" (2001, p. 2)

Other researchers highlight the pedagogical qualities of whole-class interactions (e.g., Lattimer, 2015; Msimanga, 2021). This work suggests the need to look beyond (or beneath) surface forms of classroom organisation to examine interactions between teachers and students.

Schweisfurth (2013) and (2015) defines seven standards of leaner centred education (LCE), in order to inform the implementation of LCE beyond the prescription of ‘best practice’. These “adhere to the most basic principles of LCE”, including human-rights and academic concerns, such as: “respect for the rights of learners” and “enhancement of their learning experiences” (Schweisfurth, 2015, p. 263). The standards (Figure 2, below) are intended to provide practical detail, allow for local variations, and embrace the active role of teachers as well as learners in the process of teaching and learning (ibid).

1. Lessons are engaging to pupils, motivating them to learn;
2. Atmosphere and conduct reflect mutual respect between teachers and pupils;
3. Learning challenges and builds on learners existing knowledge;
4. Dialog is used (not only transmission) in teaching and learning;
5. Curriculum is relevant to learners’ lives and perceived future needs, in a language accessible to them;
6. Curriculum is based on skills and attitude outcomes as well as content, and these should include the skills of critical and creative thinking;
7. Assessment follows up the principles by testing skills and by allowing for individual differences. It is not purely content driven or success based only on rote learning.

Figure 2 Standards of learner centred education (Schweisfurth, 2013, p. 146)

Schweisfurth’s LCE standards have been applied in studies of pedagogy in India, Kenya and Rwanda (Brinkman, 2019; Lattimer, 2015; van de Kuilen et al., 2020). Van de Kuilen et al. (2020) conclude that the standards do not adequately capture the complexities of classroom interaction. Guthrie (2018) takes a different tack, presenting descriptions of different ‘teaching styles’, intended as a non-judgemental tool for large-scale monitoring of teaching practice across distinct contexts. This reflects Guthrie’s assertion that LCE is fundamentally incompatible in some contexts, due to differing epistemologies or world-views. Guthrie asserts that the dominant epistemology in western societies is scientific, underpinned by the tradition of rationalism in western philosophy. From this perspective, knowledge is understood to be constructed through systematic and rational processes, and as a result, creativity, critical thinking and problem solving are valued. In contrast, Guthrie argues many non-western societies have a revelatory epistemology, where knowledge is understood to be revealed by deities and passed down between generations (Guthrie, 2018, pp. 18–19). Guthrie's model includes five teaching styles (authoritarian, formalistic, flexible, liberal and democratic) described in relation to four variables (teacher role – authoritarian to democratic; student role- passive to active; content approach, teaching to learning; and reinforcement- negative to positive). The 'flexible' style allows for the insight that pedagogy may be 'hybrid', including learner-centred and teacher-centred (2018, p. 207). Indeed, Guthrie suggests that the best teachers will be able to use all of the styles, which calls into question the validity (and utility) of allocating any particular 'style' to a teacher. Guthrie's model is problematic, in that it elides the complexities of lesson observation, indicating that 'teaching style' is a stable and visible phenomenon and reflecting Guthrie's notion of epistemology as also relatively fixed.

These assumptions are refuted by the theoretical discussion above, and studies I review in chapter four, which indicate the hybrid and layered nature of pedagogy (Altinyelken, 2010; Barrett, 2007; Brinkman, 2019; van de Kuilen et al., 2020) and the dynamism of 'epistemology'. For example, Brinkman (2019) finds an association between socialism in Kerala, and Keralan teachers' LCE practices and beliefs. In the context of Tanzania, Westbrook and Croft (2015) associate the inclusive teaching practices of newly qualified teachers with social policy under Nyerere's government in the 1960s. These studies suggest that the discourses and ideologies influencing teachers' beliefs and practices are layered and dynamic, and that teachers' beliefs and practices can change towards democratic and inclusive ideals.

It is widely accepted that classroom teaching and learning is connected with the institutional and social context in complex ways (Guthrie, 2018). Alexander describes differences of pedagogy between national contexts, as: "(…) not so much contrasting methods of teaching as contrasting conceptions of curriculum" (2001, p. 427). For Schweisfurth, the 'context' for teaching and learning includes "cultural, resource, institutional and policy (…)" dimensions (2015, p. 259). Her description is criticised by Guthrie (2018)for being too abstract to be practically useful. I find Bernstein's (1996) distinction between competence and performance pedagogical models a valuable analytical framework, which situates classroom communication in relation to material and institutional contextual features, and particular ideologies. Bernstein summarises the two pedagogical positions as follows:

> "Performance-modes focus upon something that the acquirer does not possess, upon an absence, and as a consequence place emphasis upon the text to be acquired, and the

> transmitter (…) From the view of competence positions, performance modes were based on the concept of deficit, whereas competence modes were considered to be based upon the concept of empowerment" (Bernstein, 1996, p. 57)

He provides a detailed typology of both pedagogical models (reproduced in *Table 2*, below).

	Competence models	**Performance models**
1. Categories: **Space, time and discourse**	Weakly classified	Strongly classified
2. Evaluation orientation	Presences	absences
3. Control	Implicit	Explicit
4. Pedagogic text	Acquirer	Performance
5. Autonomy	High	Low/high
6. Economy	High cost	Low cost

Table 2 Recontextualised knowledge (Bernstein, 1996, p. 45)

Bernstein refers to models and modes in the plural, and asserts that, in practice, modes are likely to be mixed from a "pedagogical palette" (Bernstein, 1996, p. 56). He notes that, in general, "competence" pedagogical models are characterised by non-specified locations for learning, and open time periods, and negotiated content. This allows for high levels of autonomy for learners in terms of what, how and where they learn. Performance modes in contrast are associated with defined learning objectives, within subject-disciplines and tightly controlled timetables. He suggests that this can lead to high or low levels of learner autonomy. For example, in what he terms "introverted modes" learners explore specialised discourse relatively autonomously (1996, pp. 48–49). As the citations above suggest, in competence models, the "pedagogic text" (i.e., the matter to be acquired) and evaluation of achievement focusses on what learners can do, while in performance mode the emphasis is on achieving the target performance, and evaluation identifies any shortcomings in relation to it. Moreover, in competence models the control of the teacher is often implicit, while in performance models the rules of behaviour are explicit for all learners. Bernstein's analysis indicates the close connection between classroom practice and the 'conceptualisation of the curriculum' in the education system, related to how knowledge is understood, the ways in which subjects are divided, the roles of teachers and learners, national assessments etc. (Alexander, 2001). He also highlights the material constraints on competence-mode pedagogy, which is resource intensive compared to performance mode pedagogy.

> "The costs of training teachers are likely to be high because of the theoretical base of competency models. (…) Further, there is a range of hidden costs if the competence model is to be successful in its own terms. The hidden costs are time based. The teacher often has to construct the pedagogic resources; evaluation requires time in establishing the profile of each acquirer; and in discussing projects with groups, socialising parents into practice is another requirement; establishing feedback on the acquirer's development (or lack of it) is a further time cost. Within the institution, extensive interaction between teachers over the practice is required for the purposes of planning and monitoring, as the structure is constructed rather than received. These hidden costs are rarely explicitly recognised and built into budgets, but charged to the individual commitments of teachers" (Bernstein, 1996, p. 49)

Bernstein's analysis also indicates ideological factors which contribute the recontextualization of different pedagogical models. With reference to the UK, he traces the emergence of the concept of competence across several distinct academic disciplines in the 1960s and 70s, including sociology, psychology, linguistics and sociolinguistics. He also notes that the recontextualization of competence mode pedagogy differed between primary, secondary and tertiary levels. Bernstein concludes that, despite reforms, "performance modes dominate both primary and secondary levels" in the UK (Bernstein, 1996, p. 60). Barrett (2007) reaches a similar conclusion from her study of primary school pedagogy in Tanzania, and suggests that efforts to improve teaching and learning should work within rather than against the performance mode. It also resonates with more recent claims that the dominant pedagogical models in Europe are "performance-mode" (Schweisfurth, 2013, p. 13). Crucially, Bernstein's model indicates the need to distinguish between pedagogical 'quality' i.e., teaching and learning processes, and pedagogical mode.

I apply socio-cultural theory (SCT) in order to define 'quality' interactions, within a given pedagogical mode. SCT is a view of learning through participation in social activity, first proposed by Vygotsky (1978) and developed by a number of theorists and researchers since. Vygotsky (1978) asserts that higher-order concepts and thought processes are experienced first interpersonally, before being internalised. As he puts it:

> "Every function in the child's cultural development appears twice: first on the social level, and later, on the individual level: first between people (interpsychological), and then inside (intrapsychological) (…) All the higher functions originate as actual relations between human individuals" (Vygotsky, 1978, p. 57)

Vygotsky highlighted the role of more knowledgeable others to support learners' developing competence through the 'zone of proximal development' (ZPD), a metaphorical space between what a learner can do alone and what they are able to do with support. Development occurs as the learner engages in activity, with support, in this zone, resulting ideally in the learner being able to complete the practice independently (Vygotsky, 1978, p. 86). ‘Scaffolding’ is a term which is widely used to describe the supports which teachers provide to enable students to engage with academic concepts and to participate in classroom talk and other activities. The term was proposed by Jerome Bruner (1974) from his research with adults and young children to describe the support provided to enable learners’ emergent knowledge and practice.

SCT differs from constructivism (Chisholme & Leyendecker, 2008) in that it indicates the central role of teachers in establishing meaningful learning contexts, in modelling subject-specific terms, discourses and practices, and in responsively engaging students with them. Thus, SCT seems particularly appropriate to performance-mode rather than competence-mode pedagogies and in relation to subject pedagogies at secondary level. SCT is widely cited as rationale for the central importance of verbal language and talk in classroom discourse e.g., Mercer, (1995), Gibbons, (2006) and Barrett and Bainton (2016). Arguably this assertion rests on the equation of ‘language’ with verbal language a concept which is limited in relation to the situated and expansive view of translanguaging outlined above. Further, it seems to have arisen from studies of classroom discourse conducted in well-resourced Anglo-American settings, where competence-mode pedagogy is likely to be more fully realised than in many low-resource and post-colonial contexts. As *Table 2* (above) shows, competence-mode pedagogies are characterised by weak classification of time, space, activity and evaluation, which need to be negotiated using verbal language. The role of verbal language is likely to be distinct in performance-mode classrooms.

3.3.3 Academic literacy in mathematics

I apply Moschkovich’s model of academic literacy in mathematics (Moschkovich, 2015) as an analytical tool for understanding the teacher’s construction and learners’ participation in these mathematics lessons. I selected the model following initial analysis of lesson data, as providing the best explanation of ‘what is going on here?’ pedagogically. Moschkovich’s ‘situated and socio-cultural’ approach to conceptualising the relationship between verbal language and mathematics, is coherent with the theoretical framework presented so far (Moschkovich, 2002).

Early studies on the role of verbal language for monolingual and multilingual mathematics learners, focussed on the difficulties of mathematics language compared to everyday language, and framed the problem in terms of learning technical vocabulary (Schleppegrell, 2007). This research reflected the positivist assumption that technical terms have defined, fixed and singular meanings and tended to focus on deficient language use over mathematical communication

(Moschkovich, 2002). The focus on language forms was enhanced considerably by the work of M.A.K Halliday (1978) and other systemic functional linguists (SFL) using the concept of 'register' (i.e., a variety of language associated with a particular function and situation of use). Research in this tradition highlighted the multiple meanings associated with single mathematical terms, and non-mathematical terms used mathematically (e.g., by, of, line). The linguistic focus expanded from vocabulary to include syntax, morphology, semantics and other non-verbal forms. This work highlighted the linguistic challenge, for monolingual and multilingual learners, of moving from everyday registers to more precise and abstract mathematical registers. Studies indicated this process could be complicated when students' everyday registers are in one language and mathematical language is in another (Moschkovich, 2002). The multiple-meanings perspective shifted attention from learning technical terms, to enabling students to negotiate mathematical meanings in context. However, it retained the risk of positioning students' everyday language (whether for monolingual or multilingual students) as a problem to be replaced by mathematical language whereas, everyday register can be a resource for understanding mathematical concepts (Moschkovich, 2013). A further problem with the focus on mathematical register promoted by SFL, is the separation between verbal language and mathematical practice.

Moschkovich proposes a 'situated and socio-cultural' perspective on multilingual mathematics learning, which shifts attention beyond learning mathematical terms and/or register to focus on communicating mathematically and participating in mathematical practices using social, linguistic and material resources. As she states:

> "A situated–sociocultural perspective can be used to describe the details and complexities of how students, rather than struggling with the differences between the everyday and the mathematical registers or between two national languages, use re- sources from both registers and languages to communicate mathematically. A situated–sociocultural perspective thus moves away from the description of obstacles and deficiencies to a description of resources and competencies and widens what counts as competence in mathematical communication" (Moschkovich, 2002, p. 197)

Academic literacy in mathematics is understood to comprise the integration of mathematical proficiency (i.e., the use of mathematical language including verbal and non-verbal, and multimodal forms), mathematical practices (e.g., drawing graphs, doing calculations); and mathematical discourses (e.g., presenting proofs, reading word problems, clarifying meanings). Moschkovich challenges binary distinctions between academic and mathematical language, verbal and non-verbal language and L1 and L2. Professional mathematicians use both 'everyday' and 'academic' language to communicate mathematically, often in combination, and these are legitimate resources in the classroom and learning outcomes for apprentice mathematicians (Moschkovich, 2013). Moschkovich notes that discursive mathematical practices involve distinct semiotic 'modes' i.e., symbols, visuals and language (O'Halloran, 1998, 2015) and oral, written, receptive and productive modes of communication. Moschkovich developed the model in the context of the USA, where minority language students are often kept out of mainstream classes until they are deemed have enough English to participate. She makes the case that mathematical language is part of mathematical activity and is best learnt through participation in practice. In order to support academic literacy in mathematics, teachers should:

> "(…) not address academic language as an isolated goal, but integrate mathematical proficiency, practices, and discourse whenever possible" (Moschkovich, 2015, p. 57)

The concept reflects a view of learning mathematics as participation in a community of practice (Brown et al., 1989). This analogy builds on Lave and Wenger's theory of 'legitimate peripheral participation' (LPP) (1991), a theory of learning through participation in social activity informed by SCT. The authors developed the notion of LPP, through observation of learning in a range of 'real-world' contexts such as midwifery, tailoring and factory work. The term 'legitimate peripheral participation', refers to the process of learning through participation from the edge to the core of the target practice. A key insight in relation to pedagogy is that apprentices, across contexts, learn through participation in 'full' practice and not from learning discrete 'parts' of practice in isolation. Apprentices move from peripheral roles, for example, sewing the cuff of a shirt, or assisting the midwife, to increasingly demanding roles as part of full practice. The authors note that 'experts' in these contexts do little direct teaching and provide limited verbal feedback. Instead, apprentices self-direct and self-correct through comparison of their performance in relation to the full practice which they are able to observe from the beginning (ibid.). In an influential paper, Brown, Collings and Duguid (Brown et al., 1989, p. 32) develop the idea of "cognitive apprenticeship" in which learners develop cognitive tools through participation in subject-specific practices. They critique the separation of knowing and doing in formal education and suggest prioritising doing over talking as a more concrete form of cognitive engagement. They see mathematical language as "inextricably a product of the activity and situations in which [it is] produced" (Brown et al., 1989, p. 33). In the context of mathematics classrooms this suggests that mathematical talk might profitably follow rather than lead mathematical practice. This premise is confirmed by Chval and Khisty (2009), also working with bilingual students in the USA, who present an example of bilingual students learning mathematical terms and concepts through participation in mathematical activity. The authors demonstrate how students developed concepts for the new terms through the engagement with mathematical practices, and other semiotic modes.

The focus on classroom-mathematical discourse, and verbal language as part of discourse, resonates with Bernstein's (1996) conception of performance-mode pedagogy. It also reflects the reports of mathematics teaching and learning in SSA gathered through exploratory studies, which suggest that classroom practice centres on the demonstration of mathematical activity (Barrett, 2007; Early & Norton, 2014) and aligns well with Garcia and Li's (2014) multimodal, multilingual and practice-oriented concept of translanguaging.

3.4 Chapter summary

In this chapter, I positioned the present investigation as a critical and ethnographic study of multilingual classroom communication. I outlined how the study is informed by CR, and the concepts from CDA and the ethnography of communication which I use to analyse classroom communication as constrained and enabled by material and social resources. I presented the concept of translanguaging, and my understanding of language as a situated practice which reflects and can be used to transform wider socio-political processes. I distinguished between pedagogical mode, which is closely associated with material, institutional and ideological context and pedagogical quality, which I defined as student interaction with the teacher and participation in subject specific practice. Finally, I presented the model of academic literacy in mathematics, as an analytical tool for describing and developing the multilingual mathematics lessons in this and similar contexts. In the next chapter, I review a selection of studies which investigate the teaching and learning of mathematics in EMI contexts, and pedagogy.

Chapter 4 Literature review

4.1 Introduction

In this chapter, I review two strands of literature in order to indicate the insights this study draws upon, the gaps it addresses, and the conversations it contributes to. I begin by looking in detail at a series of influential studies, which have explored the multilingual teaching and learning of mathematics in EMI contexts. I note the tendency of researchers to promote and evaluate linguistic- pedagogical approaches, which reflect academic and policy 'ideals', instead of investigating established classroom practices. An example of this is 'pedagogical translanguaging', a model which has been developed and applied by a number of African researchers in recent years. In this chapter, I reflect on the pedagogical and political advantages of the model, but question the practicality of implementation for secondary-level subject teaching in subtractive EMI contexts. In the second strand of the chapter, I turn to selected studies from comparative and international education, which indicate the need to look beyond 'pedagogical modes' (i.e., teacher-centred or learner-centred pedagogy), when making judgements about or recommendations for pedagogical quality. At the same time, I suggest that these studies would benefit from a more nuanced idea of 'language' as a means to investigate classroom interaction and student participation, and EMI. Ultimately, I make the case for reading across these two fields of language in education policy, and international and comparative education, in order to benefit from the insights and address some of the weaknesses in these closely related fields. I make the case for detailed, situated studies of established classroom practice as a basis for teacher CPD which engages with actual, situated pedagogical resources and constraints.

4.2 The multilingual teaching and learning of mathematics

There is a strong tradition of studies investigating EMI mathematics teaching and learning in SSA, with the majority of studies conducted in South Africa. In their seminal (2002) paper, Setati, Adler, Reid and Bapoo report on the "take-up" of pedagogical band linguistic practices from a Further Diploma in Education (FDE) by mathematics, science and English teachers in South Africa. The study included from 25-18 teachers over a three-year duration, working in a "variety of bilingual and multilingual" primary and secondary, rural and urban schools in Northern Province and Gauteng (2002, p. 129). Each teacher was visited at school for a week in each of the three successive years of the programme. Data included transcribed interviews with each teacher, teacher narratives and responses to questionnaires, observation schedules and notes, video recordings of some lessons and examples learner's work. Theoretically, the authors draw on Mercer's (1995) influential work on talk and 'the guided construction of knowledge', which positions talk as "a social thinking tool" and a tool "for learning", in-keeping with South Africa's constructivist curriculum which promotes "collaborative and cooperative learning, problem-solving, and meaningful communication between learners and teachers and among learners themselves" (Setati et al., 2002, p. 130). They draw on Barnes (1992) to define two 'forms of talk: 1) "learning talk", presented as synonymous with Barnes' "exploratory talk" and "most effective in learners' main language(s)"; 2) "discourse-specific talk" in English part of students' apprenticeship into subject discourse practices (ibid.). The authors present a model (Figure 3) to demonstrate possible "pedagogical journeys" from informal, exploratory talk in learners' main languages, to formal, academic writing and talk in English. The teachers' role, as they see it, is:

> "(…) to facilitate the learners' movement from informal exploratory talk in the main language to formal discourse-specific written language in English" (2002, p. 136)

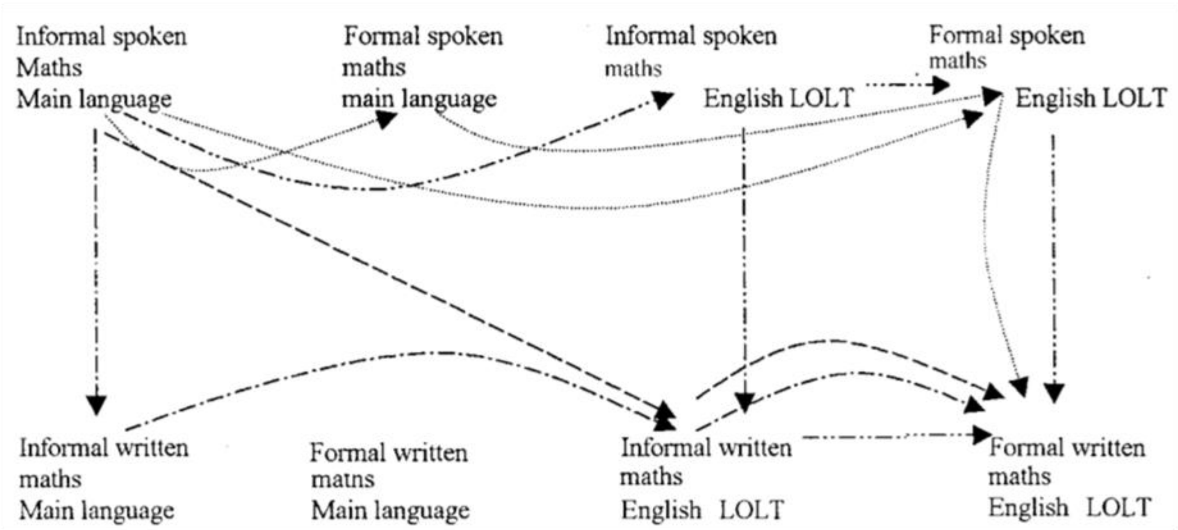


Figure 3 Pedagogical journey (Setati et al., 2002, p. 136)

The model presents a view of English and students' main languages, and informal and formal mathematical discourses as separate steps in a pedagogical journey. At the same time, the authors state a positive stance to code-switching (CS), which they deem a necessary part of classroom communication. Although the study was evaluative in nature, the sustained relationship with teachers across diverse school settings generated important insights about the impact of contextual variation on classroom communication. For example, the authors describe stark differences in the "language infrastructure" of urban and rural schools. Students in urban schools have more exposure to English in and out of school, and to print at school and in their environment than their peers in rural schools (2002, pp. 129–130). A further contrast is that classes in urban settings tend to be more multilingual, and teachers are less likely to share the main language of the majority of students, whereas in rural schools, teachers and students often share the same main language. Other factors which the researchers associate with different pedagogical practices include teachers' skills, and "differences across subjects, across levels, and across regions" (2002, p. 142). Contrary to expectations, teachers and learners in secondary mathematics classrooms made greater use of CS than those in primary. The authors propose that this is because four of the five primary schools were in rural areas where learners had less access to English outside school, meaning that teachers saw it as their task to model English. They note the "double irony", where students who are more reliant in their home language to learn, have less access to it in lessons (2002, p. 142). Overall, primary teachers felt more pressure than secondary teachers to use English, and, as described above, primary teachers in rural areas more than their colleagues in urban schools. In contrast, secondary mathematics and science teachers more frequently used learners' home languages to explain concepts, which reflects that their primary goal is teach content and not English.

The authors discuss wider socio-political factors which drive EMI, and its implementation in South African classrooms. They refer to the experience of black Africans under Apartheid, when English was restricted to segregated (white) schools is a reason why many black African families opt for EMI, a claim reiterated by other African researchers (Heugh et al., 2017; Probyn, 2021). They suggest that another factor undermining teaching and learning in indigenous African languages, is the fact that printed teaching and learning materials (TLMs) are in Afrikaans or English. The authors indicate the official status this awards English as part of classroom communication, reporting that English was the main language used by teachers and students for "public talk" (p. 138).

In terms of the impact of the FDE, they note that code-switching was an established practice among the participating teachers before their involvement in the FDE programme, but that the extent to which teachers CS and their confidence to CS increased over the duration of the intervention. Nevertheless, some teachers continued to describe CS as an undesirable necessity. The authors report that that 'learning talk' increased over the course over the study) and that groupwork increased in all classes, which they describe as "the most visible change" of the study (2002, p. 138). However, it is clear that increased groupwork does not equate with improved pedagogy. The authors report that increased talk in English lessons co-related with reduced writing, and students had few opportunities to use formal spoken or written English in mathematics and science lessons. Instead, the progression typically went from learner talk in their home language to teacher exposition in English. They conclude that more research is needed to illuminate learners' and teachers' code-switching needs in distinct contexts, and the policy message that "groupwork is good" may need to be reviewed in relation to different subjects and contexts of teaching and learning. Finally, they assert that teacher CPD needs to recognise and respond to different “language infrastructures” (Setati et al., 2002, p. 146).

Webb and Webb (2008) investigate if mathematics’ teachers’ participation in CPD enables them to use exploratory talk in their lessons, and what strategies they develop to do so. The study was conducted in South Africa’s Eastern cape, where English is the main LOLT and the majority of teachers and learners share a main language (isiXhosa). Access to English inside school is extremely limited, and there is little chance of learners hearing English out of school. Like Setati et. al., (2002), the intervention is aimed at the implementation of “collaborative and constructivist learning” in SA education policy, on the basis that “little discussion occurs in most multilingual mathematics classes (…) despite learners being seated in groups” (Webb & Webb, 2008, p. 26). The study involved 134 secondary mathematics teachers, studying the BEd (Hons) programme in six regional centres. During workshops, teachers were introduced to classroom discussion and practiced multilingual, exploratory talk whilst solving mathematical problems. Focus groups were conducted with teachers following their participation in discussions. Finally, teachers were tasked with conducting action research projects on the development of exploratory talk in their own classrooms, which generated data on the type of discussions that had occurred in classrooms, and the strategies used by teachers to enable their learners to participate. Theoretically, the authors also draw on research from the UK, citing Mercer and Sams (2006) and Mercer (1995) to assert that learners engaging in exploratory talk with other learners in groups supports the development of mathematical reasoning. The authors present their main findings illustrated with two vignettes from action research projects. They find that teachers regularly CS, defined as using English and isiXhosa in single “linguistic episodes”, using English consistently for mathematical terms (2008, p. 28)They find that increased CS co-relates with increased teacher-learner and learner-learner interactions, although teachers’ report feeling guilty about CS, which they feel is a contravention of policy and “deprives” their students of English (2008, p. 29). Teachers report that exploratory talk using L1 helped them to solve the mathematical task they were set. However, teachers engaging in exploratory talk themselves, and supporting their students to engage in exploratory talk extremely challenging. Teachers had to be frequently reminded of ground rules which had been previously discussed and accepted, students had to be “coached constantly” and “some teachers continued to believe that exploratory talk refers to any discussion in groups”(Webb & Webb, 2008, p. 29). Ultimately, like Setati et. al., (2002)the authors question about the relevance of the pedagogical and linguistic ideal they are aiming to introduce.

Setati (2005) presents a study of classroom communication in a single, upper-primary EMI mathematics class, where the teacher shares a home language with the learners. Like the previous South African studies, she asserts a strong role for verbal language in mathematics teaching and learning, which echoes the constructivist approach of the South African curriculum. As she says:

> "Part of learning mathematics is acquiring fluency in the language of mathematics, which includes words; phrases; symbols; abbreviations; and ways of speaking, reading, writing, and arguing that are specific to mathematics" (Setati, 2005, p. 448)

In contrast to the previous two studies, this is an exploratory investigation, rather than an evaluation of an intervention. In this paper, Setati foregrounds the political implications of EMI on pedagogy, arguing that the political and pedagogical are intertwined. She uses Gee's (1999) notion of discourse/Discourse, and Moschkovich's (2002) distinction between different mathematical discourses, to make links between classroom communication and wider social meanings and relationships. She finds that English is the dominant language in these lessons. 'Procedural mathematical discourses' (i.e., doing mathematics and stating mathematical facts) are conducted in English, and this lends them authority. In contrast, conceptual discourses (i.e., where meanings are discussed) are conducted in isiXhosa, the main language of the teacher and students. This results in conceptual discourse being perceived as less important by students. In a second socio-political study, Setati (2008) explores how South African teachers and learners, position themselves in relation to English and mathematics, drawing on data from two previous studies. She finds that teachers and students who position themselves in relation to English, argue for English as LOI because they consider English a language of social and economic power, without referring to epistemological issues. In contrast, students who position themselves in relation to mathematics, discussed the value of using L1 to enable epistemological access. The study indicates how international discourses around English drive EMI, the need for L1 to enable epistemological access to mathematics and the potential of focussing on mathematics to enable multilingual pedagogical approaches.

Setati, Molefe, & Langa (2008) propose moving beyond dichotomies between home/main languages and English, and between language and mathematics, to recognise them as "intertwined and in interplay" as part of classroom-mathematical practice (2008, p. 17). In this paper, the authors illustrate a proposed multilingual pedagogical strategy, using data collected over a series of four lessons in one grade 11 classroom taught by Terence, a co-author. The high school, located in Soweto, Johannesburg and learners communicate in at least four languages and Terence is fluent in eight languages. In many ways, this study precludes later models of pedagogical translanguaging (discussed below), in the contrast that is made between code-switching and translanguaging, and the emphasis on oral and written use of indigenous languages and English. The authors describe code-switching as "spontaneous and reactive" and note that "the learner's home languages are only used in oral communication and never in written texts" (2008, p. 16). Instead, they advocate:

> "(…) the deliberate, strategic and proactive use of the learners' home languages (…) We emphasise the word deliberate because with this strategy the use of the learners' home languages is deliberate, proactive and strategic and not spontaneous and reactive as it happens with code-switching" (Setati et al., 2008, p. 17)

Learners were grouped into six home language groups, and given a mathematical text with exercises to solve in English and (separately) in their home language. The text was designed to be high cognitive challenge, and contextually relevant to learners. The authors conclude that the transparency of language enables learners to focus on conceptual mathematics, indicating the pedagogical value of strategic and systematic use of L1. The also reflection the logistical challenge of producing written texts in six languages, an issue in linguistically diverse urban contexts.

Also working in South Africa, Probyn (2009) explores the linguistic and pedagogical practices of science and mathematics teachers in township and rural schools, where teachers and learners share a main language, using data from four small scale research studies. In line with the previous studies cited here, she takes a 'language as a resource' orientation to CS, and reports that CS is common in many classrooms, where many teachers "utilise the linguistic resources of the classroom in a skilled and responsive way to achieve a range of cognitive and affective teaching and learning goals" (Probyn, 2009, p. 124). Nevertheless, CS is often not sanctioned in teacher training; and teachers have negative associations with CS, which they see as "(…) illicit, a sign of linguistic and pedagogical incompetence" (2009, p. 129). This attitude may obscure research on classroom practice, as demonstrated by two teachers who admit changing their language practices when observed, despite being assured by the observer to teach as normal. Probyn describes the tensions which teachers experience, between 1) content teaching and language teaching; 2) the policy of EMI and the classroom reality (which necessitates CS); and 3) between teacher and learners' affiliation with their home language and the official, and economic arguments for using English. She points out the paradox that schools opt for EMI, despite students' limited proficiency in English and the ML language policy of South Africa (p. 125). Other negative impacts of EMI include students feeling "inferior" using English publicly, which limits their verbal participation in lessons (2009, p. 120) and content examinations conducted in English failing to measure content competence. Regarding teacher CS practices, Probyn notes considerable variation between teachers, which she attributes to diverse teacher attitudes; attitudes of school principal, teaching staff and parents; teaching contexts and constraints including teachers own proficiency; and the language demands of the subject. She finds that teachers CS for cognitive and affective purposes, and often use the shared ‘home language’ to introduce concepts and short switches into isiXhosa to gain and hold students’ attention e.g., using short tag questions. A further detail is that teachers “Xhosalise” English, using Xhosa prefixes with English terms (e.g., ‘i-cell’). Teachers state that this is unconscious, and Probyn speculates that it is a means to “appropriate the terminology and reduce the alienation of the subject matter” (p. 132). Finally, Probyn reports that CS is just one of many multimodal and discursive practices which teachers use in these lessons. In her words:

> “Codeswitching was not the only strategy used by teachers to support learning: they also repeated key terms and concepts, spoke more slowly, used gesture and voice tone to support communication; consolidated concepts on the chalkboard, related ideas to learners’ own experiences, and in the case of science, used demonstrations and analogies” indicating teachers are “finely tuned to the needs of the learners” (Probyn, 2009, p. 133)

Nevertheless, only verbal data is included the lesson extracts presented in the paper.

Early and Norton’s (2014) investigation in a secondary school in rural Uganda, focuses on teachers’ perspectives and practices with regard to the use of English as a medium of instruction (MoI) across the curriculum and in the “micro and macro context of the school” (2014, pp. 674–675). The authors describe the material conditions of the school as typical of rural government schools in Uganda. Class sizes range from 80-120 students, caused in part by the expansion of basic education to include secondary school in 2007. There is one room at school with electricity, few coursebooks or other materials and no science lab. As a result, as one teacher describes it: “the teacher is the whole bible” (2014, p. 680). In addition, students are often the first in their families to attend secondary school, meaning that support for study outside of school is limited.

Teachers express the opinion that the transition to English from primary four is too early, and support the use of learners’ home languages at school, although they often do not share a home language with learners (Uganda is reported as having 343 languages). Teachers report that school authorities and community members perceive the use of African languages at school as evidence that teachers lack linguistic and pedagogic skills, and students are reluctant to speak in class because of making mistakes with English. Other students, confident in their use of local English, do not realise it is ‘sub-standard’ by national standards. National examinations are conducted in English and marked in Kampala, and teachers report that students lose marks for their ‘non-standard’ English across subjects. Teachers point to inequity between urban and rural students in Uganda, as the former have substantially more exposure to English and print.

Mathematics lessons in a government secondary school in rural Rwanda: A case study

The study also provides considerable detail around classroom communication, indicating that teachers employ a range of nuanced, flexible and systematic approaches to EMI subject-teaching. All teachers teach the subject specific terms and registers of their disciplines in English. Kaikaira, a mathematics teacher, explains that "most of the scientific names are the one thing that we have to teach in English" addition to "(…) the language of working through the steps and procedures and giving explanations for their reasoning" (2014, pp. 682–683). The teachers also use locally found materials, "local vernacular knowledge" and a range of multimodal resources, such as "'realia and drawings' and 'demonstrations, illustrations, pictorial representations and charts" to communicate with and engage students (2014, p. 682)One science teacher explains that he uses, "(…) experimentation and hands-on as often as possible" to provide access to content and language (2014, p. 683)The authors conclude that the teachers in this school:

> "(…) exercise agency and make great efforts to address both the language and content needs to their students. They use multimodal pedagogical approaches: spatial, performative, visuals, and demonstrations, and draw on available local resources, together with students' background knowledge, to make abstractions more concrete and to scaffold students' language and content learning. Wherever possible, they provide the students with rich linguistic input, scaffolded by other modes, and walk a fine line in the use of codeswitching in their classroom practices, although because of the examinations, they correct and assess not only content knowledge but also 'correct' English usage" (Early & Norton, 2014, p. 686).

They present a series of recommendations, including the need for evidenced-based language in education policies which recognise local language practices as legitimate; advocacy with communities and policy makers for the use of learners languages at school; focus on language in teacher education in relation to distinct subjects and "bi/plurilingual and multimodal pedagogies"; examinations which do not penalise students for perceived deficits in English; and for "collaborative, capacity building action research" which supports teachers to produce case studies of policy enactment and "transformative pedagogies" and to inform understandings of language and content learning in poorly resourced schools (p. 687).

The studies presented in this section have generated some key insights about how EMI is constructed by mathematics teachers in distinct socio-linguistic and institutional contexts. Notably, secondary teachers feel less responsible for teaching English than their primary peers. Further, while use of L1 is widespread, teachers see this as a negative practice, and/or limit the practice because of the negative perceptions of others. Finally, teachers use a range of verbal and non-verbal strategies to enable students to access language and mathematics.

The studies reflect a shift in understanding from language/s and language and mathematics as separate (Setati et al., 2002) to the view that language and mathematics as part of a single, intertwined process (Setati et al., 2002). Setati (Setati, 2005, 2008) explores how socio-political associations with English drive support for EMI and shape classroom interactions, and the potential of focussing on mathematics to enable use of L1 to promote epistemic access. The majority of the studies promote a talk-based 'constructivist' pedagogical ideal informed by research conducted in relatively well-resourced schools in the UK and USA and problems transferring these pedagogical models to classrooms in SSA are evident. Setati et al. (2002)and Webb and Webb (2008) reflect on the challenges of ensuring that groupwork and exploratory talk is pedagogically worthwhile. Probyn (2009) and Early and Norton (2014) describe the linguistic-pedagogical strategies teachers have developed in their classroom contexts, which may be a firmer basis for pedagogical development than distant theoretical ideals.

Next, I turn to more recent work on pedagogical translanguaging, which has further developed understanding of multilingual classroom communication, whilst, I suggest, remaining more focussed on ideal than actual classroom practice. There has been considerable attention to the potential of translanguaging as a pedagogical approach for multilingual education from African researchers. One focus of discussion has been distinguishing between code-switching (CS) and translanguaging. As the studies above indicate, the term code-switching was used, before the spread of the term translanguaging, as a kind of catch-all for multilingual communication which involved more than one language whether the 'switch' occurs at word, sentence or text level (Clegg & Afitska, 2011). The term CS is critiqued for implying a fragmented and deficit view of multilingual communication, compared to the holistic and integrated view of translanguaging (Garcia & Li, 2014). Nevertheless, a number of researchers continue to use CS to describe the oral use of L1 alongside English in EMI classrooms, which is compared negatively to 'pedagogical translanguaging': the planned and purposeful use of learners linguistic and metalinguistic resources for learning(Makalela, 2015; Probyn, 2015). For instance, Poo and Venkat (2021) define code-switching as movement between two languages through translation or substitution of words or phrases. They assert that CS is responsive and unplanned, in contrast to translanguaging which they describe as purposeful and planned where 'planned' refers to teachers' intention to work with multiple representations. Pedagogical translanguaging refer to the use of two or more standard languages with the aim of developing bi or tri-literacy (Heugh et al., 2019; Hornberger & Link, 2012). The concept is illustrated through Makalela's description of an in-service training program:

> "The teachers had to develop teaching philosophies that included statements around the value of more than one language (…). They had to demonstrate the simultaneous use of

> more than one language and sustain this throughout the lesson phases. The basic criterion was that each learner would re-tell or rewrite the texts in a different language from the language of input” (Makalela, 2019, p. 243)

Probyn (2015) illustrates ‘pedagogical translanguaging’, through a study of eight, grade eight science classes in township and rural schools, which aimed to identify teachable bilingual practice that could inform teacher development. Probyn defines CS as “switches between languages of relatively short duration”; ‘translation’ as repetition by the teacher of lesson content or instructions in the learners’ home language; and ‘translanguaging’ as the use of both languages in an integrated and coherent way (2015, p. 220). Echoing the pedagogical models already cited in this chapter, she proposes ‘pedagogical translanguaging’ to refer to the strategy of using learners’ home language for exploratory talk and English for presentational talk. Probyn finds that although all teachers say they CS to help students understand, seven out of the eight teachers CS minimally. Of the four teachers who doe CS regularly, she distinguishes between teachers, who CS “in response to cues from the learners that they had not understood” (2015, p. 227) and the more sustained and systematic translanguaging practice of one of the teachers (teacher B). Teacher B uses more isiXhosa than other teachers, but also more English. Likewise, learners in the class spoke more isiXhosa, and more English than learners in other classes (with the exception of a class where the students gave presentations). The paper concludes with a recommendation that the pedagogical and language practices demonstrated by teacher B are used to inform CPD for teachers in similar contexts.

The concept has been further developed in a number of recent studies, which demonstrate how systematic use of L1 for oral and written tasks, enables epistemic access and to challenges monoglossic ideologies and language hierarchies. Banda (2018) demonstrates how multilingual classroom discourse in a Black township secondary school in Cape Town enables learners to achieve power, agency and voice as consumers and producers of English texts. He advocates for language in education policy which puts translanguaging at the centre of classroom practice in multilingual South Africa. McKinney and Tyler (2019) present an example of pedagogical practice from a Year 9 Science class in a South African high school, designed to move beyond language ideologies and enable bilingual isiXhosa/English students to use their full semiotic repertoires for learning Science. Charamba (2020) explores translanguaging practices used with form one General Science students in a rural secondary school in Zimbabwe. He finds that the use of instructional materials written in home languages and translanguaging practices affect learners’ performance in science tests, creates a comfortable learning environment for all learners, and enables them to consider the stratification of languages and scientific knowledge. These studies share an emphasis on enabling flexible multilingual communication, and the use of standard indigenous African languages and English for oral and written, receptive and productive tasks. The studies indicate the pedagogical value of enabling learners to use their full linguistic and cultural resources for learning, and the political value of critiquing established linguistic and academic hierarchies.

I have chosen not to apply the concept of pedagogical translanguaging to this study because I consider it reflects a linguistic and pedagogical ideal which may be impractical for many teachers. The studies cited above include pedagogical approaches such as student exploratory talk in L1 in groups which have proved highly challenging to implement in classrooms in SSA, over decades (Guthrie, 2018; Schweisfurth, 2013). Msimanga (2021) makes the case for promoting translanguaging as part of whole class discussion because groupwork is limited in South African classrooms, despite decades of reform efforts. A further critique of ‘pedagogical translanguaging’ is the extent to which the model promotes language separation, and ‘balanced bilingualism’, rather than the integrated view of multilingual competence (Garcia & Li, 2014). While bi/tri-literacy is a valuable aim, it is questionable to what extent it is practical to expect subject-teachers to teach literacy in addition to their subjects. The assumption appears to be that all teachers see themselves as language teachers, as they are asked to do in South Africa. However, in most EMI settings, subject teachers assume that language teaching is the responsibility of the English course and the English teacher (Lin, 2019; Richards & Pun, 2021)A further limitation is the focus on verbal communication in these studies rather than multimodal communication, which is more consistent with the concept of ‘translanguaging’ (Garcia & Li, 2014; Lin, 2019) and the multimodal nature of mathematics communication (O’Halloran, 2015). Jaspers points to the paradox of translanguaging advocates celebrating teacher agency, whilst criticizing teachers who fail to adopt prescribed linguistic-pedagogical practices. He suggests that researchers’ focus on language policy may obscure their appreciation of the complex concerns and dilemmas which teachers negotiate in daily practice (Jaspers, 2018). This critique highlights the need for studies which investigate how teachers negotiate the multilingual teaching and learning of mathematics in EMI contexts, including the political and pedagogical aspects of their practice, to inform efforts to strengthen teachers’ pedagogical resources, and address constraints on practice.

4.3 Pedagogy and context

The second strand of studies reviewed here, focus on pedagogy and learner centred education. The studies indicate key aspects of context which influence pedagogy, which include material, institutional and ideological factors. These studies reinforce the need to look beyond/beneath ‘pedagogical mode’ in making judgements about quality, and to enable teachers to identify and develop their pedagogical resources and address ideological and material constraints on classroom communication.

Barrett (2007) investigates pedagogy in government primary schools in Tanzania using interviews with teachers in 18 schools across four districts in two regions of the country, and 28 lesson observations; 23 in two relatively well-resourced schools and five in two rural and under-resourced schools. Overall, she concludes that pedagogy is performance-mode (Bernstein, 1996). Classrooms are "reminiscent of an auditorium" with a wide stage on which the teacher performs (2007, p. 287). A further strategy, common "especially in mathematics", is "to call a pupil to the front of the class to demonstrate the solution of a problem. Other pupils would then be invited to point out corrections" (2007, p. 285). Barrett details factors which favour performance-mode pedagogy in this context. These include: strict divisions between subjects in the school curriculum, limited time to complete and ambitious curriculum, and the importance of examinations in Tanzania. In addition, she points to the lack of coursebooks for students in lessons; large class sizes; teacher fatigue due to large workload and physically and emotionally stressful living conditions; and lack of CPD. Teachers in the study consider that their lessons reflect learner centred principles, and cite question-and-answer routines, which were observed in every lesson, as an example of participative practice. Barrett indicates that there are aspects of pedagogical quality in lessons. Teachers observe and respond to students as they present information in lessons. She uses the analogy of a game of catch, where the teacher throws a ball, and students either manage to catch the ball, or don't. In response, the teacher throws again: "(…) devising alternative strategies for projecting the subject matter" (2007, p. 286). Teachers confirm this is a conscious and purposeful pedagogical strategy. Barrett concludes that pedagogy is overall in the performance mode, but there is a degree of mixing in teachers' "pedagogic palette" (2007, p. 288). She suggests that improvement in quality will be achieved largely within the performance mode.

Altinyelken (2010) investigated the implementation of Learner Centred Education (LCE) in eight Ugandan primary schools, where teachers' understanding of LCE was dominated by grouping children and providing them with cooperative tasks. All teachers express enthusiasm for LCE during interviews, and say they implement LCE in their classrooms. Altinyelken uses an observation rubric to assess teachers' implementation of LCE, and concludes that "(…) pedagogical reforms permeated classrooms to a lesser extent than alleged by teachers" (2010, p. 162). At the same time, she describes classroom practice as 'hybrid', with a combination of traditional and reform pedagogies (ibid.). Like Barrett (2007), this indicates a pedagogical resource to build on. Altinyelken lists a series of contextual factors which inhibit the implementation of LCE. These include limited, "hectic and hurried" teacher training, large class sizes, lack of teaching and learning materials (TLM's), time pressure, which "(…) adversely affected teachers' tendency to organise group activities, practical work, and discussions", low teacher morale linked to low salary and incentives, high stakes examinations, and English medium of instruction (EMI) (Altinyelken, 2010, pp. 164–166). These contextual limitations suggest that radical 'transformation' may be challenging, but that pedagogical improvement can still be achieved.

Brinkman (2019) investigates the LCE beliefs and practices of 60 primary school teachers from the three Indian states of Bihar, Kerala and Maharashtra through a combination of surveys, interviews and lesson observations. The study also included 30 interviews with teacher educators, and 40 interviews with "educationists" from across the country. Brinkman devised indictors for evaluating teachers' LCE beliefs and practices, allowing for quantitative analysis of the co-relation between teacher beliefs and practices. Brinkman finds that teachers hold a wide range of beliefs, and often express mixed beliefs and beliefs which contradict LCE. For example, the belief that some students are incapable or unworthy of learning; that knowledge is given to students (rather than constructed by them); and that education is a tool for socio-economic mobility (rather than for social transformation). Brinkman's findings indicate connections between teachers' beliefs, between teacher beliefs and 'widely held' beliefs in their states, and between teacher beliefs and practices. Brinkman found that the teachers' beliefs were reflected in the teacher educator and educationist interviews, indicating that these are "widely held" and as such, she concludes that "(…) teachers can be seen as victims as well as vehicles of these wider ideological beliefs" (2019, p. 15). Brinkman also notes that LCE beliefs tend to coalesce. In her words:

> "A teacher who believes all humans possess equal worth and learning ability is more likely to value democratic teacher-student relationships" (Brinkman, 2019, p. 17)

Moreover, she finds a co-relation between individual teacher beliefs and surrounding ideologies in the three states. Specifically, teachers in Kerala demonstrate higher LCE belief and practice scores, which Brinkman attributes to the egalitarian ideologies of Christianity and Communism in contrast with Brahmanical ideology in Bihar and Maharashtra. She also finds that there is a strong co-relation between teachers' stated beliefs and their practices: teachers who express high LCE beliefs have mid or high LCE practices and teachers who express low LCE beliefs have mid or low LCE practices. Brinkman highlights the need to move away from a focus on LCE practices which may be ill-suited to the classroom contexts in India, towards engaging teachers with LCE principles connected to their beliefs and supporting them to develop feasible and appropriate pedagogies. She points out that egalitarianism and LCE are not 'western' concepts, citing the Indian social reformers Tagore and Gandhi among others. She advocates "transformative" teacher CPD that combines experience, action and reflection, connected to teachers' beliefs and practices, and that includes teachers, teacher supervisors and teacher educators (2019, pp. 24–25). This study indicates the complex ways in which teachers' beliefs and practices relate to context specific discourses and social movements.

The final study I explore in detail here, is Van de Kuilen, Altinyelken, Voogt and Nzabilirwa's (2020) comparative study of the recontextualization of LCE by primary and secondary school teachers in Rwanda. The purposive sample comprised 12 primary and 12 secondary school teachers, from four primary and four secondary, rural and urban schools selected for their strong performance in national examinations. Entry to these schools is restricted to students who perform well in examinations, and the majority of students were from middle-class homes. Lesson observations were conducted using an observation rubric based on Schweisfurth's seven LCE standards (Figure 2). The authors acknowledge that their use of an observation rubric led to a researcher effect on the data collected. They critique the validity of the standards to evaluate pedagogical quality, which they conclude do not to justice to "(…) the complexity of teaching and interplay of various factors" (van de Kuilen et al., 2020, p. 10)The study indicates convergences and divergences between primary and secondary teachers. Both sets of teachers associated LCE with groupwork, and defined LCE as learners being more active than the teacher, with the teacher acting as a "facilitator" (2020, p. 8). All teachers talked positively about LCE, which they associated with collaboration and conflict prevention; skills for employment and economic growth; and improved student motivation and learning outcomes. While teachers' support for LCP is "unconditional", they mentioned challenges such as lack of coursebooks and time, reporting that LCP lessons were time-consuming to prepare and conduct (2020, pp. 8–9). There were notable differences between primary and secondary teachers. Secondary teachers described their role in evoking "(…) knowledge construction through questioning, judging what is right or wrong, or adding to what learners bring into the classroom", while primary teachers tended to describe lessons as focussed "only on children" (2020, p. 8). They report that most teachers connect new learning with prior knowledge, and encourage interaction between students in their lessons. In primary classes, most teachers saw children's prior knowledge as the sole source of knowledge while secondary school teachers took a more directive role in knowledge construction. All teachers appeared to equate LCP with groupwork, and in all but one lesson, students worked in groups. In secondary lessons, teachers also used whole class questioning to enable "learners to discover knowledge themselves" (2020, p. 10). The authors question the benefits of groupwork, given the low cognitive challenge of groupwork assignments. They note that large group sizes and limited numbers of coursebooks per students, especially in primary classes, hindered student participation in groupwork. During whole-class interactions, they found that primary teachers provided compliments which were often "meaningless" or for wrong answers and little constructive feedback. Secondary teachers tended to be more directive, providing informative feedback, or directing students to give feedback to peers (2020, p. 12). The researchers report that EMI is a problem undermining LCE, although only four out of 24 teachers mentioned EMI as a problem. They report that almost half of the teachers in both groups provided language support "often with the help of multisensory teaching, such as making gestures or providing illustrations" (2020, p. 14). This study indicates some problems with simplistic representations of LCE, in particular for primary school teachers who associate LCE with groupwork and limited teacher intervention. The generalised pedagogical ideal of LCE communicated to primary teachers undermines teaching and learning in their classrooms. The study indicates that secondary school teachers' focus on their instructional subjects enables them to take a more directive role, which the researchers perceive to be beneficial.

These detailed studies explore teacher beliefs and practice regarding LCE in the context of their schools and wider social discourses. The studies point to a range of contextual factors, associated with performance mode pedagogy, which suggests that this 'mode' is unlikely to radically change. The studies add weight to the insight that 'pedagogical mode' does not equate with pedagogical quality (Alexander, 2001; Bernstein, 1996; Guthrie, 2018). Barrett (2007) and Altinyelken (2010) show that 'performance-mode' pedagogy can be hybrid, with constructivist, responsive elements. Van de Kuilen et. al. (2020) identify a converse association between simplistic LCE beliefs and practices and the quality of pedagogical interactions. They also indicate that secondary teachers are better equipped to recontextualise LCE in relation to their subject-pedagogy: they focus on subject-specific knowledge and practice *and* engaging students.

4.4 Chapter summary

The studies presented in this chapter challenge simplistic binaries between learners' home languages and EMI and between teacher and learner centred practice by illuminating the complexities and qualities of pedagogy and language use as agentive and situated practices. They point to the ways in which teachers construct classroom practice, in interaction with learners, policies and contexts (i.e., time and material resources and constraints, school level, type and location, and instructional subject). The present study is part of this conversation.

Fairclough (2013) suggests that trans-disciplinary research can enrich understanding across distinct research fields. In this chapter, I presented two 'sets' of studies focussed on EMI and pedagogy respectively, which illustrate this point. The EMI-focussed studies demonstrate increasingly nuanced insights about the ways in which teachers and learners use language as a resource, and the complex, layered and often indirect action of EMI on classroom practice and teacher and learner beliefs about practice. However, the majority of studies prioritise 'learner-centred' pedagogical approaches, such as exploratory talk in groups, which reflect national curriculum priorities, and research conducted in well-resourced Anglo-American settings, over classroom realities. In addition, researchers tend to focus on verbal language separate from other semiotic modes and discourses. This is limited in relation to the multimodal concept of translanguaging (Garcia & Li, 2014; Lin, 2019) the multimodal language of mathematics (O'Halloran, 2015) and practice-oriented approaches to mathematics teaching and learning (Brown et al., 1989), in multilingual classrooms (Chval & Khisty, 2009; Moschkovich, 2015). The second set of studies have generated increasingly nuanced views of pedagogical quality beyond teacher- and learner-centred binaries, and the close connections between teachers' beliefs and practices and their classrooms contexts. However, engagement with issues around EMI is limited and, like the EMI studies, student participation is primarily judged in terms of their verbal contribution. Indeed, the majority of studies in both groups employ normative pedagogical and linguistic frameworks to collect data and/or evaluate practice. As a result, linguistic and pedagogical 'problems' and 'solutions' indicated by researchers may show more about researchers' ideals than classroom realities. In contrast, the studies which take a more exploratory and inductive approach to data collection and analysis i.e., Barrett (2007) Probyn (2009) and Early and Norton (2014), show how teachers observe and respond to students in their lessons, using a range of semiotic resources and discourse practices including but not limited to verbal language and talk. There is a need for studies, which move beyond normative pedagogical and linguistic models, to provide detailed and nuanced accounts of classroom pedagogical and linguistic practices in specific school levels, types and in relation to particular instructional subjects. These insights are needed to inform teacher CPD which recognises, validates and enables inclusive and interactive classroom practices, identifies and mitigates the socio-political constraints on practice and challenges deficit discourses about pedagogy and language in education policy and research.

Chapter 5 Research design and methodology

5.1 Introduction

In chapter three, I situated this study in a tradition of critical and ethnographic research into multilingualism and language in education policy (Martin-Jones & da Costa-Cabral, 2018) and outlined the meta-theoretical, theoretical and conceptual foundations of the study. In this chapter, I describe how I have operationalised these ideas, in the design and implementation of the study. I begin by describing why I selected case study as an appropriate approach for investigating complex social issues. I review the ethical concerns raised by the study, including my position as a white, European researcher conducting research in Rwanda, and working with local researchers. I describe the school, where the lessons take place, and provide some background information about the teacher and students. I outline the various methods of data collection and data sets which resulted. Finally, I describe the process of data analysis.

5.2 Case study

The term 'case study' can be used to describe an approach to research, an analytical approach and the outcome of research (Duff, 2008, p. 21). In a sense this study combines these three meanings. I have conceptualised 'these mathematics lessons' as a case, which I understand as an 'open system' (Archer, 1998) dialectically related to wider social processes and relationships. My analysis comprises identifying hierarchical units of interaction within the case, and drawing connections between these units and the material and social context of lessons i.e., the school, the community, Rwanda and international. The outcome of this investigation is a case study, with information about the school, the teacher and students and detailed description of classroom interaction. The purpose of the case study is to highlight the particularities of these lessons, and the ways in which they relate to wider social processes and to identify pedagogical resources and constraints to inform teacher CPD in Rwanda and comparable contexts. Case study is appropriate for the investigation of complex, contemporary phenomenon, which can be studied in-depth and as a whole, with attention to relationships and processes, rather than being broken down into isolated parts (Denscombe, 2007, p. 36). The approach is used in studies which combine an interest in classroom practice and the social, historical and political context of practice. For example, Setati et. al. (2002) and Altinyelken (2010). As here, case study research is used to examine phenomena in a 'natural' setting, for example classroom interaction as it occurs day to day at school. This intention reflects a view of social interaction as situated and phenomena, dynamically connected with the context in which it occurs.

Key characteristics of case study research include: "(…) boundedness or singularity, in-depth study, multiple perspectives or triangulation, particularity, contextualisation and interpretation" (Duff, 2008, p. 29). Case study researchers often use a range of methods to capture different kinds of data and include a range of perspectives. The aim is not to identify a single 'truth', but to reflect the ways in which meanings and practices are constructed by different people, and to draw links between practices across contexts (Duff, 2008). I have opted for a single case design in this study, the case being 'this mathematics class', with 'multiple embedded units of analysis' which are single, recorded 'mathematics lessons' and 'speech events' within lessons (Duff, 2008, pp. 112–113). I understand this as an 'open system', with complex connections between units of interaction (speech events) and the wide, social and material context (Archer, 1998). I consider the social, historical and political context of 'this mathematics class', which occurs in a particular school, and community, and in national and international context, as essential in understanding classroom interaction and in making connections between interactions in these lessons and wider social processes (Duff, 2008; Fairclough, 2013). I am part of this complex social system, and this case study is the result of decisions I have had to make about how much detail to gather and present about each 'layer'.

A common criticism of case study is that individual cases lack explanatory power because they are not directly generalisable. As Duff points out, this criticism often stems from researchers in the positivist tradition, who seek to develop general laws and principles by investigating single variables across large data sets (2008). Case study is appropriate, from the perspective of 'transcendental realism' because it allows for a combination of empirical data (which is understood to be inevitably partial) and theoretically informed analysis to identify 'invisible', actual and real processes (Bhaskar, 2008) (3.2.1). Moreover, the researcher's own positionality, and account of their knowledge building process and interactions in the research context can form part of the case. As detailed above, this study reflects the view that particular, situated interactions are related to social, historical and political mechanisms and structures in complex ways. My intention is to provide a rich and detailed description of this particular case, as a basis for exploring the relationship between this case and underlying mechanisms and structures. I consider that this case is at once unique, and relatable to other contexts with similar characteristics (e.g., secondary mathematics lessons in Rwanda and comparable low-resource, postcolonial EMI contexts) (Blommaert & Dong, 2010). To some extent then, I claim that the findings of this study are generalisable. However, I view 'generalisation' as a partial, critical and agentive process, and encourage readers to reflect upon the ways in which features identified in this context align with and differ from other contexts (Duff, 2008). To enable the critical reading of this study, I detail my position as a researcher (1.4, 10.8), I provide national and local contextual detail (Chapter 2, 5.5), and I describe the research design and analysis, and provide extensive data (6, 7, 8, Appendix D, Appendix F) in this report.

5.3 Ethics

Ethics in research refer to moral principles which guide researcher's behaviour as they interact with research participants; collect and analyse data and disseminate findings. Social researchers are expected to:

- "respect the rights and dignity of those who are participating in the research project;
- avoid any harm to the participants arising from their involvement in the research;
- operate with honesty and dignity" (Denscombe, 2007, p. 141)

In this section I discuss the measures I took to maintain these ethical standards in this study.

5.3.1 Informed consent

The right for participants to choose to be part of the study, or not, on the basis of accessible and accurate information about the study, is a core principle of ethical social research (ibid.). This can be hard to achieve in situations with low literacy and high power-difference. The issue of informed consent is especially fraught in low-income contexts, where large power differences can exist between stakeholders spanning "northern" and "southern" contexts (Hultgren et al., 2016); and between academics and school staff, school and home, and adults and children (ibid.), (Cohen et al., 2011). Low levels of print literacy and lack of familiarity with research can also be a problem. Indeed, a number of researchers call for ethical processes adapted for participants in low-income settings (Hultgren et al., 2016; Shamim & Qureshi, 2013). When research takes place at school, some participants may consciously opt in or out, but others may be involved in the study by virtue of being at school while the research is underway (5.6.5) or 'be volunteered' by someone in a senior position.

To mitigate these issues, I prepared participant information sheets (Appendix B) and consent forms (Appendix C) for school leaders, the teacher, students and their families. The forms described the study and introduced the researchers. It explained why the school had been chosen and what participants would be asked to do. Participants were assured that their data would be protected and they would remain anonymous in any research reports. They were invited to contact local researchers or me for further information, using a Rwandan phone number or email. In addition, the contact details of the Research Integrity and Governance Manager at the University of Southampton was provided in the event of complaints. The local researchers translated the forms into Kinyarwanda, and visited the selected school to talk to school leaders and teachers about the study. Ultimately, I collected signed consent forms from the teacher, all students and a parent/guardian for each student.

Once a teacher for the study had been identified, the students in his class were informed about the study, by the teacher and local researchers. Students were given participation information sheets and consent forms to take to their families and asked to tell them about the study. Students had the option of not appearing in camera or in audio recordings, and not attending interviews or focus groups. Other staff and students at the school were 'opted in' to the study as a result of the head teacher's agreement for the school to participate. The head teacher was asked to inform other staff and students about the study, and tell them that any interaction with the researchers was voluntary and that information about them would be kept private.

5.3.2 Protecting the interests of participants

A further key ethical principle of social research is that participants should not suffer mental or physical harm as a result of their participation in a study (Denscombe, 2007). The main strategy to mitigate the psychological stress to the teacher and students as a result of being part of the study was communication. This was done in the first instance using participant information sheets and consent forms (Appendix B and 3; 5.3.1). The information was repeated verbally by researchers when we visited the school, and teachers and students were encouraged to ask us questions. The teacher and students were shown the recording equipment, and students could choose to sit behind the video camera. In order to mitigate disruption to lessons, for students in the mathematics class and other students at school, I discussed the importance of this with local researchers, the mathematics teacher and other teachers at school. In order to protect the privacy of participants, all data were stored on password protected pen and hard drives. Data on the SD cards of the audio and video recorders were deleted after being copied. In reports of this research, pseudonyms are used for participants and places, and features which might identify them in photographs, such as signs and faces, have been blurred. I have also removed some contextual information which could be used to identify the teacher and school.

I compensated the teacher for his time, paying him for each of the observed lessons at a rate which was agreed with the local researchers. Students in the study were given sets of mathematical stationary, and the school received the video camera.

5.3.3 Ethical clearance

Three separate ethical clearance procedures were completed for this study. The first procedure was part of the application process for affiliation with the University of Rwanda College of Education (URCE). Once affiliation was obtained, the study underwent a second review from the Ministry of Education, and was granted a research permit. In parallel I applied for ethical clearance from the University of Southampton ethical committee (ERGO no. 40206). In each case I was required to submit a research proposal with research objectives, questions and methods; translated participant information and consent forms; a CRB check and personal identification documents.

5.4 Working with local researchers

In order to conduct this study, I employed the services of two university lecturers (both also PhD students) as local researchers. The local researchers assisted me with obtaining informed consent from research participants, and collecting and translating data. I led a face-to-face training day for the local researchers at the start of the study, where we practiced using recording equipment, and reviewed interview guidelines and ethical protocol. We maintained contact throughout the study through Skype, WhatsApp and email. Working in multilingual research team is often necessary in studies where lead researchers are 'outsiders' in relation to the sociolinguistic communities they are investigating e.g., (Altinyelken, 2010; Westbrook & Croft, 2015). It serves practical purposes and brings benefits whilst raising a number of ethical issues, especially when conflated with issues of race and post-colonialism (Hultgren et al., 2016).

I relied upon the local researchers to identify possible schools for the study, and to obtain informed consent from participants. Furthermore, the local researchers had a major role in data collection, and translation of data. They recorded 8 out of the 10 lessons and conducted the post-lesson interviews with the teacher and groups of students after the observations, following guidance provided by me. The local researchers translated Kinyarwanda to English in the audio data, including the teacher and student microphone recordings from lessons and the interview recordings. They did not transcribe English, paralinguistic or non-verbal information. This study would not have been possible without the Rwandan researchers, and that will be reflected through co-authorship of publications resulting from the study. At the same time, I have been careful to retain intellectual ownership of the study design and analysis of findings in order to meet the requirements for PhD research.

On the practical side, Hultgren, Erling and Chowdhury (2016) note that employing local researchers to collect data can be more cost effective than flying out international researchers.

This was an important concern for me, along with environmental issues and limitations on the time I had available for travel, as a self-funding PhD student, with a young child, living in Germany. In addition, it seemed likely that Rwandan researchers would be less disruptive to life at the school, than me as a white, 'foreign' researcher (ibid.). However, the insider/outsider distinction proved complex. It seemed to me, and the local researchers, that the teacher was more relaxed with me than he was with the local researchers. This may be explained by the fact that, as university lecturers, the local researchers are senior to the teacher in the education system. Both local researchers have worked as teacher trainers for national teacher CPD programs, and evaluate trainee teachers during periods of practicum at school. Other studies of multilingual research teams point to the challenges facing 'insiders', who, despite sharing linguistic resources with participants may still be regarded as 'outsiders' in other ways (e.g., Gregory and Ruby, 2011 in (Martin-Jones & Martin, 2017, p. 190). I presented myself to the teacher as a student researcher and a former language teacher, and he seemed to judge these roles as relatively unthreatening. Altinyelken reports a similar experience from her study in Ugandan schools, which she attributes to being seen as an outsider (Altinyelken, 2010, p. 160).

Hultgren, Erling and Chowdhury (2016) point to ethical problems where researchers from the "Global North" guide the work of researchers from the South. In order to mitigate power imbalances, I discussed the issue with the local researchers and identified ways to ensure that they benefit professionally from their work on this study (Bond & Tikly, 2013, p. 437). I am committed to future academic collaboration with the local researchers, including co-authoring papers or chapters based on this study.

5.4.1 Gaining access

I worked with contacts in Rwanda to identify and access to the sample school and research participants. My contact at URCE contacted potential schools which met the criteria I stipulated (5.5), using the translated participant information sheet (PIS) (Appendix B). Once a head teacher had agreed for their school to be involved in the study, the local researchers visited the school with PIS for teachers and met with teachers to discuss the study.

5.5 Sample, setting and participants

The sampling strategy employed in this study was purposive, an appropriate strategy for case study research given the aim of understanding the unique complexities of a single case (Duff, 2008). Indeed, purposive sampling was applied in the majority of studies reviewed in the previous chapter. I decided to focus this study on a series of lessons with a single mathematics teacher and class, in order to gain detailed insight in to how this teacher constructs lessons, with these students at this school as the basis for drawing connections between classroom communication and wider social discourses. This decision reflects insights about the context specific nature of pedagogic and linguistic practice (Setati et al., 2002), and my view of pedagogy as constructed by teachers in interaction with students in a particular school and subject context (3.3.2). Further, I decided that a sustained study of lessons and teacher and student perspectives on lessons with a single class would enable me to ‘get below the surface’, and understand how the lessons work in their own terms. Of the studies cited in the previous chapter, only Setati et al. (2008) adopt a similar approach, following a series of lessons with a single class, although the study piloted a pedagogical innovation rather than seeking to understand practice separate from an intervention. The other studies cited in chapter Four opt for larger and more diverse samples (Setati et al., 2002; van de Kuilen et al., 2020; Webb & Webb, 2008) and yield a range of important insights, separately and collectively. The distinctive sampling strategy of this study enables it to generate complementary insights to the existing body of knowledge, for example through providing detailed descriptions of pedagogical practice.

5.5.1 The school

The school is a combined primary and secondary school. The mathematics teacher described the school as a “twelve years basic education school” (12YBE) (Fieldnotes, 03.09), referring to the government policy of 12 years free basic education for Rwandans (2.3) (Williams, 2019). The school is government owned and funded, and is relatively well-resourced but not exceptional compared to other ‘12YBE’ schools I visited in Rwanda (1.4). The school is situated in a compound, about 500m square, fenced by hedges. There are four main blocks of single-story, brick buildings. The primary school block is situated in one far corner; a second central block includes the deputy head’s office, a secretary’s office, a teachers’ room and an ICT room. The ICT room contains eight computers, which have electricity but no internet. A third block, which faces the second across a small yard, contains the lower secondary classrooms and a library room, which is full of books and exam papers stacked on shelves. There are class sets of coursebooks for the new curriculum, which some teachers take to lessons. I don’t see students using the library. On the far side of the compound, the fourth block contains the upper secondary classrooms. The blocks are roughly the same size, although there are far more primary than secondary students, and lower-secondary than upper secondary students. Between the lower and upper secondary blocks is an open space, used for sports and assembly. In the yard, between the administrative block and the lower secondary rooms, is a neatly tended planted border, and a flag pole with the national flag flying. The secondary school teachers’ room leads directly from the school grounds, and the door is kept open. Teachers move in and out of the room freely, but students only enter if accompanied by a teacher (for example to help the teacher carry books). If students want to talk to a teacher, they ask at the door and wait outside until the teacher comes outside. The teachers' room contains a single, tall cupboard, in which individual teachers store their papers and books in cardboard boxes. The room is bordered by the same desks with benches attached as are in classrooms. Teachers use the room to prepare lessons and complete lesson records in a book labelled "journaux de classe". One wall of the teacher's room is covered with a chalk-drawn timetable for the secondary school, with different colours, and codes for each class, teacher, and subject. The deputy head teacher's office leads off from corner of the teachers' room. Teachers and students only enter this room when invited, and the door is kept closed. It contains a chair and desk, and a cupboard. On the wall is a hand-drawn poster of the school's enrolment and dropout figures from the previous year. On the first day, the deputy head showed me a stack of files kept in a tall locked cupboard in the room, which include lesson observation forms and the school plan. He also showed me an observation form, in English, which he uses to observe teachers, following the requirements of REB. Each class of students at the school have their own 'homeroom', and teachers move between classrooms. During lessons teachers close the classrooms doors, which are generally open between lessons. I didn't see the deputy head go inside a classroom while I was at school, although he walked around the grounds each day. Students are responsible for keeping the room clean and tidy. The walls of classrooms are bare. The mathematics classroom is the second of a in block of four lower-secondary rooms. The block is brick, with slatted windows. There is a blackboard the length of the front and the back of the room although in the lessons I observe, only the board at the front is used.

5.5.2 The teacher

The mathematics teacher is in his late twenties, and lives with his wife and small child in a village about 3 Km from the school. Like the other teachers, he is smartly dressed and sometimes wears a white lab coat over his clothes. In general, he is one of the quieter and more reserved teachers. Similar to the majority of teachers I meet in Rwanda, he appears to take his job seriously although he expresses concerns about the working conditions. In particular, he is disappointed at the low salary for a graduate, and in relation to other kinds of public servant in Rwanda. Like all public servants, he works a minimum of 40 hours a week. The vast majority of these hours are timetabled for teaching, leaving little time for lesson preparation and marking. The teacher has a bachelor in mathematics education from the university of Rwanda, and has worked at this school for 6 years. He comes to school by bike each day but would prefer to drive a car or motorbike. He speaks critically about the students at the school and their families, as lacking the talent and/or financial resources needed to attend private school. The teacher's negative statements about this 12YBE school, and the students at this school, resonate with the teachers in Williams (2019). At the same time, this teacher has himself come from a deprived background and worked hard to get to his current position. He grew up in a village somewhere outside Kigali, and describes his family as rural and poor. He is the first person to go to school and university in his family. His schooling was disjointed. The genocide and civil war occurred at the end of his time at primary school. He had to take a break before starting secondary school for financial reasons. In this time, he worked in the factory. He went to a government boarding secondary school, that his family paid for. The boarding school had a partner school in the UK, and there were exchanges between teachers and students from both schools. After he finished secondary school, he worked in factories for a couple of years, before joining Kigali institute of education to train as a secondary school mathematics teacher. He talks passionately about mathematics and enjoys the status that being a mathematics teacher seems to convey at school (Fieldnotes, 04.09). He states that he was always talented at mathematics, that it was easy for him. He started university in 2009. He completed one year under the French system, and then the switch was made to English medium. He says that he learnt some English while at university, and then more as he did practical placements in schools around Kigali.

5.5.3 The students

There are 52 students in this senior one mathematics class. Of these, 33 are female and 19 are male. The students are aged between 12 and 16 years old, and the age gap is visible. Some students are the same size or bigger than the teacher, while others are much smaller. All of the students wear school uniform trousers or skirts and shirts.

In focus groups, students talk enthusiastically about learning mathematics, which they seem to see as relevant to them. In contrast they talk about learning English as necessary to get through school, and to pass exams but seem to see little value in English beyond school (05.SFGT). There are large disparities in the level of engagement between students during the lessons, although the expected behaviour for most students in most activities (i.e., looking and listening) make it hard to judge. A few students seem to volunteer at every opportunity, while the majority volunteer seldom and some not at all, during the recorded lessons.

The teacher talks about the students in derogatory terms, which seems to be related to his negative view of '12YBE schools'. He describes how the removal of examination requirements for 12YBE schools has meant that many students moved to secondary level without the necessary knowledge in mathematics or English. He said that parents who can, send their children to private schools. In addition, students who score highly in the end of primary exams can obtain part or full scholarships to private schools. As a result, government twelve-year basic education schools have large numbers of students from families who are not able to pay school fees, and students who have not excelled in the end of primary exam. The teacher referred to students as “lacking talent” and their parents as being not educated, and not interested in education (Fieldnotes, 04.09). These comments echo those reported by Williams (2019).

5.6 Data collection methods

5.6.1 Recorded lessons

Ten, double-period (80 minute) mathematics lessons were audio and video recorded from June to October 2018. The local researchers recorded the first and final four lessons. I observed and recorded the two lesson observations in the middle of the data set (5.6.1, *Table 3*).

Lesson observation was a central method of this study, as in the studies citied in chapter 4. My aim was to gather a rich and detailed data from these lessons that could be used to practically inform teacher CPD (Lattimer, 2015). I was keen not to use a lesson observation rubric as a filter for data collection, which is a weakness of several studies reviewed here (Altinyelken, 2011; Brinkman, 2019; Setati et al., 2002; van de Kuilen et al., 2020). Instead, I selected do use unstructured lesson observation (Cohen et al., 2011). This meant gathering a rich data set, with minimal filtering or analysis at the point of collection. It resulted in a rich, ‘raw’ data set, which I have been able to explore using a range of analytical categories and techniques. It has meant that, as I developed claims from my analysis of selected part of the data, I have been able to test these claims against the wider data set.

I decided to collect data from at least 10 complete lessons, recorded over a minimum of three months. I was keen to be able to distinguish between the dynamics of particular lessons (caused, for example by particular mathematical objectives) and underlying patterns of interaction across lessons. I wanted to minimise disruption for the teacher and students and be realistic about the number of lessons I would be able to analyse. I chose to record ‘whole lessons’ as defined by the school timetable rather than recording parts of lessons. I was keen to see how the teacher and students constructed lessons, which I might miss by analysing a part of the lesson. At the same time, I accept that I will have missed connections between particular lessons and the lessons directly before and after, and have not explored how the teacher constructs a whole unit of learning with students, which would span several consecutive lessons. Ultimately, 10 double-period mathematics lessons were recorded, over a five-month period and covering a range of mathematical focus areas (e.g., statistics and geometry).

I recognise that the presence of a researcher and/or recording equipment in the lessons means they were to an extent, constructed as 'recorded lessons' and would differ from non-recorded non-observed lessons. In addition, I made a number of practical decisions around lesson recordings which influenced the data I collected, which was necessarily partial and limited. I decided to use a static video camera and two external microphones in order to obtain a visual record of lessons, with minimal disruption to the lesson and capture public and private teacher and student talk. The video camera was placed at the back of the room, on the desk or mounted on a tripod. The position enabled me to capture a broad view of the classroom, from roughly half-way down to the front of the room which was where the majority of teacher-student interaction happened. The camera did not obstruct teacher or student movement in the room, and its placement enabled students to sit 'off-camera' if they chose (5.3.2). The camera's microphone was sufficient to capture the majority of talk. One microphone was worn by the teacher, and the second was placed on the desk in front of a group of students. The placement of this second microphone varied across lessons, as students were asked to volunteer to host the microphone at the start of each lesson. Further, after lessons, researchers took photos of the blackboard, coursebook and student notebooks.

Table 3 below summarises the data set from recorded lessons. *Table 4* provides a key for the codes used.

Lesson	Date	Mathematical focus	Video, audio and transcripts	Photos
1	06.13	Direct and indirect proportion	06.13.V1 06.13.LT 06.13.SMA 06.13.SMT 06.13.TMA 06.13.TMT	06.13.CBP1 06.13.CBP2 06.13.CBP3 06.13.SN1 06.13.SN2 06.13.SN3 06.13.SN4 06.13.SN5 06.13.SN6

2	06.20	Point and line	06.20.LT 06.20.LV 06.20.SMT 06.20.SMA 06.20.TML	
3	06.27	Angles on a straight line	06.27.LT 06.27.V1 06.27.V2 06.27.V3 06.27.TMA 06.27.SMA 06.27.SMT	
4	07.10	Angles in triangles	07.10.LV1 07.10.LV2 07.10.LV3 07.10.LV4 07.10.LV5 07.10.TMA 07.10.TMT 07.10.SMA1 07.10.SMA2 07.10.SMA3 07.10.SMA4	
5	09.05	Histograms	09.05.LT 09.05.V1 09.05.V2 09.05.V3	

			09.05.V4 09.05.V5 09.05.SMA1 09.05.SMA2 09.05.SMA3 09.05.SMT 09.09.TMT	
6	09.06	Pie-chart	09.06.LV1 09.06.LV2 09.06.LV3 09.06.LV4 09.06.SMA 09.06.SMT 09.06.TMA 09.06.TMT	
7	09.12	Frequency polygon	09.12.LT 09.12.TMA 09.12.TMT 09.12.SMA 09.12.SMT 09.12.LV1 09.12.LV2 09.12.LV3 09.12.LV4	
8	09.17	Cuboids	09.17.LV1 09.17.LV2 09.17.LV3	09.17.BWP1 09.17.BWP1 09.17.SNP1

			09.17.LV4 09.17.LT 09.17.SMA 09.17.SMT 09.17.TMA 09.17.TMT	09.17.SNP2 09.17.SN3 09.17.SNP4
9	09.19	Cylinders	09.19.LV1 09.19.LT 09.19.SMA 09.19.SMT 09.19.TMA 09.19.TMT	09.19.BWP1 09.19.BWP2 09.19.BWP3 09.19.BWP4 09.19.SNP1 09.19.SNP2 09.19.SNP3 09.19.SNP4 09.19.SNP5 09.19.CBP1 09.19.CBP2
10	10.09	Prisms	10.09.LV1 10.09.LV2 10.09.LV3 10.09.SMA 10.09.SMT 10.09.TMA 10.09.TMT	10.09.SNP1 10.09.SNP2 10.09.SNP3 10.09.SNP4 10.09.SNP5 10.09.SNP6 10.09.SNP7 10.09.SNP8 10.09.SNP9 10.09.SNP10

				10.09.SNP11 10.09.SNP12 10.09.SNP13 10.09.SNP14

Table 3 Recorded lesson data set

Example code	Description
09.19.LV1	Date (day/month), lesson video, file number
09.19.LT	Date, lesson, transcript
09.19.SMA	Date, student lesson microphone, audio
09.19.SMT	Date, student lesson microphone, transcript
09.19.TMA	Date, teacher lesson microphone, audio
09.19.TMT	Date, teacher lesson microphone, transcript
09.19.BWP1	Date, board work photo, file number
09.19.SNP1	Date, student notebook photo, file number
09.19.CBP1	Date, coursebook photo, file number

Table 4 Recorded lesson data set key

5.6.2 Post-lesson interviews

Post-lesson interviews are used to gather participant impressions of particular lessons, and support lesson analysis in this study, as in several of the studies reviewed in the previous chapter (Altinyelken, 2010; Barrett, 2007; Setati et al., 2002, 2008; van de Kuilen et al., 2020). In this study, post-lesson interviews were conducted with the teacher and groups of students after six of the 10 observed lessons.

The purpose of the interviews was to gather the teacher and students' perspectives on lessons. This reflects the ethnographic orientation of the study, and the commitment to understanding the perspectives of participants. At the same time, I recognise that these interviews were distinct social encounters constructed by researchers and research participants and not a window on objective truth. Further, I recognise that participants perceptions of these mathematics lessons and related factors are themselves partial (3.2.1).

In order to minimise disruption to the teacher and students (5.3.2), interviews were conducted in the break time following the observed lesson. They were kept short and participation was voluntary. The interviews were semi-structured, in order to minimise the influence of researchers on participant responses whilst providing a measure of structure (Robson, 2011, p. 280). The teacher was asked to describe the objectives of the lesson, and what he thought was more or less successful about the lesson and why. Students were asked to describe what they had done in the lesson, what they enjoyed and didn't enjoy and what they learnt. The students were interviewed in a group, as in Setati et al. (2008). Students were invited to stay in the room to talk to the local researcher about the lesson. The teacher was not present during this interview. The local researcher spoke to the teacher in the school grounds or in the staffroom. The interviews were conducted in Kinyarwanda and audio-recorded. The local researchers translated the interviews into written English. *Table 5*, below shows the post-lesson interview data set.

Lesson	**Date**	**Mathematical focus**	**Post-lesson interviews**
1	06.13	Direct and indirect proportion	06.13.TIA 06.13.TIT 06.13.SGIA 06.13.SGIT
2	06.20	Point and line	06.20.SGIA 06.20.SGIT
3	06.27	Angles on a straight line	06.27.SGIA 06.27.SGIT 06.27.TIA 06.27.TIT
4	07.10	Angles in triangles	
5	09.05	Histograms	09.05.TIN
6	09.06	Pie-chart	
7	09.12	Frequency polygon	

8	09.17	Cuboids	09.17.SGIT 09.17.SFGA 09.17.TIT 09.17.TIA
9	09.19	Cylinders	09.19.TIT 09.19.TIA 09.19.SGIA 09.19.SGIT
10	10.09	Prisms	

Table 5 Post-lesson interview data set

5.6.3 Teacher interviews

Two further interviews were conducted with the mathematics teacher. The first, short interview was audio recorded and translated by the local researcher. The interview was semi-structured (Robson, 2011, p. 280), and in the interview the teacher was asked to comment on his views about teaching mathematics and working with English as a medium of instruction. The second was conducted by me during the week of fieldwork at school. The purpose of the interview was to hear from the teacher, in his own words, about his personal and professional background and his views about his current role. This reflects my understanding of the teacher as the central agent in constructing these lessons, and the importance of his biographical experience in this regard. The interview was “semi-structured” (Robson, 2011, p. 280), to allow me to listen to how the teacher framed his narrative, and the issues which he raised (ibid.). Discussion centred around the following topics:

- Family background
- Education (primary, secondary and tertiary)
- Views on mathematics and mathematics education
- Experience working at this school
- Experience of new curriculum
- Attitudes to English, Kinyarwanda and French

- Professional motivation and aspirations
- Professional challenges and concerns

The interview took place off the school grounds and after school hours to enable a longer and less formal conversation than would be possible at school, and lasted for approximately three hours. I encouraged the teacher to provide extended answers by using probes, and checked meanings by asking him to give examples or explain more fully (ibid.). I invited the teacher to use French or English, and the interview occurred mainly English and occasionally French. I decided not to audio record the interview to avoid restricting the teacher's responses and establishing an overly formal tone. I made notes during the interview, and additional notes the same evening to capture the main content of what the teacher had said. I wrote an analytical summary of the notes as part of a fieldwork report which I wrote after the week. Data from this interview consist of the notes I made in my notebook during and shortly after the interview, and an account of the interview which I wrote after returning to Germany using the original notes (see *Table 6*, below).

Data code	**Description**
05.TIT	Transcript of interview conducted by local researcher with the teacher in May 2018
Fieldnotes 03_06.09.	Notebook containing all fieldnotes from this period.
04.09.TIN	Notes of the teacher interview written afterwards.

Table 6 Teacher interview data set

I had several shorter conversations with the teacher during fieldwork (5.6.5), and maintained contact with the teacher, through Whatsapp, since.

5.6.4 Student focus groups

In addition to post-lesson interviews, three focus groups were conducted with volunteer students in order to explore their attitudes to the teaching and learning of mathematics at this school. The first focus group was conducted by the male local researcher during a visit to the school in May 2018. Students were asked to share their perspectives on learning mathematics and using English as a medium of instruction. The focus group lasted approximately 20 minutes, and was audio recorded and translated by the local researcher. In addition, I conducted two focus groups with the students in this mathematics class, following the two lessons which I observed and recorded.

The focus groups each lasted about 20 minutes, and took place in the students' classroom during break-time. Students were invited to attend at the end of the observed lessons, and 23 and 27 students attended the two focus groups respectively. The aim of the focus group was to gain some more general insights into students' experience of the teaching and learning mathematics at this school. In the first focus group, students discussed what they like and dislike about learning mathematics and English. In the second focus group, students talked about the qualities of good teachers and students at this school. The focus groups both followed the same format. I began by reminding participants of the commitment to protect privacy in this study, and asking participants not to discuss responses after the session (5.3.2). Next, I presented the discussion topics, and gave participants 5 minutes to discuss the topics with their group. Finally, I asked groups to share their answers with the whole group. After individual contributions, I invited other students to indicate if they agreed or not, and to respond. A local researcher was present in both focus groups to translate where needed. Students were invited to use Kinyarwanda and English and mix languages. The focus groups were not audio recorded. I took notes during the focus groups and made supplementary notes afterwards.

A summary of the data set is presented in *Table 7*, below:

Data code	Description
05.SFGT	Transcript of focus group with students conducted by local researcher
09.05 SFGN	Notes from focus group conducted by me
09.06 SFGN	Notes from focus group conducted by me

Table 7 Student focus group data set

I selected focus group as a method to interact with students because I thought that this would be less intimidating than talking to students individually. Moreover**,** the format of the focus group provided students chance to talk about their ideas together, before sharing them with me and thus allowed for more considered responses (Cohen et al., 2011, p. 433). In addition, focus groups are a means of observing interaction between participants, for example how participants respond to other participants suggestions and the extent to which the views of individuals are shared among others in the group (ibid.). There are several limitations of focus groups. My main concern was confidentiality, because unlike myself and the local researchers, students have not formally agreed to protect each other's data. In order to mitigate this, I discussed the issue of privacy at the start of each of the focus groups and asked that students respect each-others privacy by not discussing 'who said what' after the session. A further limitation, was the relatively formal nature of the interaction during focus groups. This was, I think, the result of several factors. It was the local researcher and I (the 'adults') who were asking most of the questions, which gave the interaction the unequal and familiar pattern of lessons. The focus groups took place in the classroom, and this may have contributed to the formal sense of a lesson. The students remained seated while the local researcher and I stood at the front of the room, and when students spoke to the group they stood. This interaction was data in itself, indicating the formal teacher-student relationships at this school. Student responses were also revealing, as 'model answers' for example, students described reasons why they enjoyed doing groupwork in mathematics (e.g., so the strong student can help the weaker student). Their answers indicated that they are familiar talking about groupwork, although very little groupwork was observed in the recorded mathematics lessons. At the same time, students described the role of the good student as 'following' the teacher, indicating that this more 'traditional' pedagogical discourse was legitimate at this school in theory as well as in practice.

5.6.5 Participant observation at school

Participant observation is a central method in ethnographic research, where the aim is to observe social activity in its natural setting (Cohen et al., 2011, p. 298). Specifically, participant observation refers to a mode of observation in which the observer is not "merely passive", but accepts that they are a participant playing a role in the situation they are investigating (Duff, 2008). Participant observation enables me to gain insight into discourses and ideology at school, the immediate environment for the mathematics lessons and a central layer between national language policy, and the teacher's construction of policy in lessons (Cincotta-Segi, 2011a; Fairclough, 2013; Ricento & Hornberger, 1996). Setati et al. (2002). Lattimer (2015); Early and Norton (2014) and van de Kuilen et al. (2020) include periods of participant observation at school. Participant observers are, inevitably, part of the social situations they observe and this means that researchers need to be reflexive about their influence on the interactions they are observing (Blommaert & Dong, 2010).

I attended school for two periods of participant observation. Firstly, for a school day, in early June 2018; and then for a week of school, in September 2018. In order to mitigate the ethical issues involved with me gathering data at school (5.3.1, 5.3.2), I was open with staff and students about my purpose for attending school, and made myself available in the staff room and in the school grounds to answer questions about myself and the study. I did not approach staff or students (with the exception of the deputy head teacher who I informed when I arrived and when I was leaving school each day). At the same time, I tried to appear friendly, by smiling and responding when spoken to. I spent a lot of time making fieldnotes, which provided a useful way of being 'semi-present', and was often a way into conversation with teachers, who asked what I was writing. The time was spent "being in the school", (Blommaert et al., 2005, p. 383) and this yielded rich data about staff and student identities, school procedures, routine interactions and events. *Table 8* (below) summarises the data set which I gathered through participant observation. This includes conversational interviews with school staff, lesson observations, and participation in routine school activities and non-routine events.

Conversational interviews	**Lesson observations**	**Routine activities**	**Events**
Deputy head teacher	Francois senior 1 mathematics (same class as in recorded lessons)	Journey to and from school	Teacher's meeting
Beatrice, English teacher secondary school	François, senior 4 mathematics	Lunchtime	Assembly
Antoine, English teacher and School-based mentor	François, senior 6 mathematics	Break time	A group of students being disciplined
Francois, maths teacher	Beatrice, senior 1 English	Time in staffroom	Preparing for visit of district officers
Musa, history teacher	Roger, senior 6 mathematics	Walk around school grounds	Visit the ICT room
Roger, final year secondary mathematics teacher trainee (supply teacher for maths)	Musa, senior 1 history		Visit the library
Ken, second year biology and chemistry teacher trainee (supply teacher for Kinyarwanda)	Ken, senior 1 Kinyarwanda		
Pascal, Biology teacher			

George, Primary school English teacher			

Table 8 Participant observation summary

5.6.6 Fieldnotes

I made fieldnotes to record contact with local researchers and research participants, and other experiences in the time I spent in Rwanda related to this study. The fieldnotes include a range of texts e.g., plans for meetings, notes made during meetings, drawings of places, and notes made after meetings or events. Entries are dated, and distinction is made between observation and description and analysis. A summary of this data set is presented *Table 9* below.

Data code	**Description**
06.03	Notes from meeting with local researchers
06.06	Notes made during first visit to school
06.06.LO	Lesson observation notes
09.03_06.FN	Notebook containing all fieldnotes from this period.

Table 9 Fieldnotes data set

5.7 Data analysis

Critical realism has informed the analytical approach taken in the present study, which combines ethnographic and critical analysis. My first, ethnographic task has been to understand 'what is going on here?' within lessons, using primarily lesson observation data and teacher and student comments on lessons. Secondly, I have looked to explanations for particular beliefs and behaviours, and connections between aspects of interaction and the wider social context. I have conceived this as a 'positive critique' (Fairclough, 2013) aimed at identifying ways in which the teacher mitigates EMI and how these might be further enabled through teacher CPD, as well as a 'negative critique' aimed at identifying constraints on classroom communication and how these might be addressed (3.2.2).

I further developed the conceptual and analytical framework for this study through the process of data analysis, as I tested concepts and models in relation to the data to judge their explanatory potential. I found the concept of translanguaging to be useful, but not the model of 'pedagogical translanguaging'. Bernstein's pedagogical modes (1996) enabled me to conceptualise the relationship between the teachers' construction of lessons and the material and institutional context of lessons. Moschkovich's 'academic literacy in mathematics' (2015) proved valuable for understanding how the integration of mathematical English and mathematical practice.

I began by transcribing data, and experimented with different methods of transcription (5.7.1). Next, I identified 'speech acts' and patterns of interaction within each lesson, and defined 'speech events' (3.2.3), which I further subdivided into lesson activities and instructional units (5.7.2). I came to see how the teacher and students used particular 'contextualisation cues' to establish different activities, and index EMI and CBC within activities. For example, the teacher began the activity I term 'demonstration' by holding the chalk aloft, and asking students, in English "who can come and try?" in a way which simultaneously served to construct 'demonstration', EMI and the student-centred CBC. I coded interview and focus group data, and data from participant observation at school, using codes which I derived from the data such as:

- Students learn by being active
- Students learn by seeing and doing
- Students learn by helping each other
- Language is not important for mathematics
- These are CBC lessons
- Groupwork is not always suitable for mathematics and science
- Students lack English
- Students lack talent
- English is a problem/ is not a problem
- Teach in English, explain in Kinyarwanda
- English is a foreign language, Kinyarwanda is our national language

Drawing on CDA (3.2.2), I identified connections between teacher and student comments and my observations and lesson data (Heller, Pietikaeinen, & Pujolar, 2018). I sought to identify 'interdiscursive' connections between data sets, and connections between different statements, speech events and practices and 'monoglossic ideology'. For example, the teacher's claim that English is not a problem, reflected his flexible use of English and other semiotic resources which was enabled because he considered himself a mathematics and not a language teacher. Students saw English as problem, both because they conflated linguistic and cognitive challenge (i.e., they first encounter new mathematical concepts in English) and because they felt that ‘translanguaging’ was a sign that they lacked English, an assumption linked to monoglossic ideology. Thus, while monoglossic ideology is in some ways enabling for the teacher, it constrains students’ confidence and communication. At school level, there was much discussion about the importance of Kinyarwanda for national unity, and English use in the playground or teachers’ room seemed to be extremely limited, my presence at school notwithstanding. I kept a journal through the process of data analysis, which was a practical tool to keep track of my work, and a means to reflect upon the conclusions I was drawing and questions I had (Blommaert & Dong, 2010).

5.7.1 Transcription of lesson data

Transcription is an analytical and descriptive processes, which is why I include it in this section. The transcription of lesson data involves a series of decisions about what to describe and in what level of detail (Heller, Pietikaeinen, & Pujolar, 2018). Transcriptions included written and spoken verbal language; paralinguistic cues such as volume, intonation, and pause; non-verbal language such as gaze, gesture and movement; and mathematical modes such as symbols and visuals; and use of classroom artefacts such as the chalk, the blackboard, the textbook, rulers etc. I transcribed all 13 hours of recordings in detail, and then selected instructional units to analyse more closely. I tested various analytical categories, such as ‘languages’, mathematical discourses (e.g., conceptual and procedural discourses) (Setati, 2005), and codes from my analysis of interviews and focus groups (i.e., ‘teach in English and explain in Kinyarwanda’; ‘students are active’, ‘students help each other’). A central concern, given my understanding of lessons as complex ‘open systems’ was balancing attention to ‘parts’ i.e., language forms and speech acts and ‘wholes’ i.e., speech events (3.2.3). Notably, some speech acts were only visible in the context of speech events. For example, I can to see that students’ non-response to teacher’s bids for them to volunteer indicated to the teacher that students required additional task support. I identified ‘contextualisation cues’ which were associated with distinct speech events, and were used by the teacher and students to co-construct such events. For example, the teacher holding out the chalk to the class to signal ‘demonstration’. Mostly, contextualisation cues combined different linguistic forms. For instance, demonstration is signalled by the teacher verbally with the phrase ‘who can try?’ and rising intonation, through turning to and gazing over the class, and through a pause in which students are invited to volunteer. Transcripts of the instructional units presented in chapters 6 and 7, are included in Appendix D and Appendix F.

5.7.2 Instructional units and activities

I defined two hierarchical units of 'speech event' (3.2.3), which I term instructional units and activities. The first of these, 'instructional units', refers to sequences of interaction bounded by instructional objectives from the perspective of the teacher. In chapter 6 and 7 I present two units of instruction: 'frequency polygon' and 'surface area of cuboids'. The mathematical focus of these units is clearly delineated by the teacher for students at the start and end of the unit, and remains visible throughout the unit through the heading written on the board. I use instructional units as the unit of analysis for "mathematics lessons", the case at the centre of this case study. I analyse sub-units of interaction, such as activities and language, in relation to pedagogical units because I found that these 'sub-units' only 'make sense' in relation to full pedagogical units. This observation has important implications for classroom discourse research, indicating that extracts should be analysed in relation to and as part of instructional units, and not in isolation. The second unit of interaction which I have found useful in this study is 'activity'. Activities are sub-units of interaction within instructional units, with distinct roles for teachers and students and communicative objectives, which serve the instructional purpose of the instructional unit (Lemke, 1990). In these lessons, I categorised six activity types. These were:

1. Preparation
2. Presentation
3. Demonstration
4. Summary
5. Student questions
6. Individual and groupwork

Of these, the first four were present in all instructional units in the data set while the last two were less frequent, with instances of group and individual work least frequent of all. Activities are constructed by the teacher and students. For example, the teacher turns to face the class, and begins to talk to signal the end of 'preparation' and the beginning of 'presentation'. Students look up towards the teacher, and stop talking to each other to co-construct the activity with him. The boundaries between these activities were often negotiated, as we see in Chapter 6 (6.4) and 7 (7.4) when the teacher bids to begin 'demonstration', but the students prompt him to provide additional information in the format of 'presentation'.

5.7.3 Mapping, tracing, connecting and claiming

Heller et al. (2018), define four stages for data analysis in critical socio-linguistic studies: mapping, tracing, connecting and claiming. My process of analysis included these four stages, with a great deal of overlap and non-linear movement between stages. I found that I often needed to return to earlier stages or work across stages as the analysis developed. The first task, mapping, refers to the production of a description of the data set (ibid.) and includes transcribing the lessons (which, as I noted in 5.7.1 above, was an ongoing process), typing up fieldnotes and interviews and naming audio, word and visual files. In the second stage, 'tracing' I began to look for explanations for the descriptive data (Heller, Pietikaeinen, & Pujolar, 2018). Specifically, in relation to the lesson transcripts I was concerned with the interactive order of lessons, the structure and content of activities and units of interaction; how these began and ended and fitted together. Once I had a sense of how lessons worked, and what happened in lessons, I began to look for connections between the lesson data and other data gathered at school. This included how the teacher and students talk about lessons; how the teacher describes his history; and other interactions which I observed at school. I did this, using a simple word document, by categorising interview, focus group and fieldnote content thematically, grouping comments under topics such as 'teacher/student perspectives on mathematics/EMI', and in relation to tentative claims such as 'learning mathematics by seeing and doing', and 'language is not important for mathematics'. I also drew on my knowledge of discourse in the wider education system (e.g., the claim made by a former Ministry of Education official that 'language is not that important for mathematics' (Pearson, 2014). I was looking to explain what was happening in lessons, and formulated hypothesis which I was able to test against the data. Finally, at the claiming stage I experimented with formulating and testing statements about the data in response to my three main research questions. I looked for data which contradicted claims. Ultimately, I selected a limited number of claims about lessons, grounded in and verified by the data, which were relevant to the purpose of the study and the academic conversations it contributes to.

5.7.4 Respondent validation

Verifying conclusions with research participants is a means to test claims, and can be used to strengthen the claims made. For example, Barrett (2007) reports how she discussed her conclusions with Tanzanian teachers, and gained insight into their pedagogy in the process. Duff (2008) warns of the risks associated with checking data with participants, who may request to have data withdrawn or re-written. I maintained contact with the mathematics teacher while I was writing up the study, mainly via WhatsApp. Once I had developed tentative conclusions, I asked the teacher to review them. I wrote a summary of conclusions regarding the teacher's construction of lessons, formatted as a Likert style survey, for the teacher to read and respond to (Appendix H). He also asked to see a draft of the full thesis, which I sent to him. After he completed the survey, we had a conversation over WhatsApp to talk in more detail through each point. I offered to include one of the local researchers for possible interpretation, but the teacher declined. There were no major differences of opinion, although the teacher was at pains to point out that he teaches in English and uses the CBC coursebook in lessons. He appeared concerned that the study indicates he does not follow government policy. This reminds me to communicate conclusions ‘responsibly’ to ensure that no harm can come to the teacher or local researchers as a result of their participation in the study (Duff, 2008). For example, I will emphasise how the teacher works *with* official policy *interpreting* policy as part of his pedagogy, and in response to his students. The teacher has asked to be sent the final PhD thesis and any publications that come from the study.

5.8 Chapter summary

Case study approach is appropriate for exploring the complexities and particularities of the teaching and learning of mathematics in a rural, government school. The study complied with rigorous ethical procedures from the University of Rwanda, the Rwandan Ministry of education, and the University of Southampton. I worked with local researchers, who helped me to identify a school for the study, to communicate with research participants and collect and translate data. Data were collected through recorded lesson observations, post-lesson interviews with the teacher and groups of students, teacher interviews and student focus groups, and a period of participant observation at school. Analysis involved mapping and connecting data within and between sets to refine units of analysis, claims and conceptual tools framed by the research questions and the purpose of the study.

6 How does this teacher construct these mathematics lessons?

6.1 Introduction

In this, the first of three analysis chapters, I address the first research question: How does this teacher construct these mathematics lessons? This question reflects the recognition that, as instances of social reality, lessons are constructed by teachers and students in interaction, whilst teachers have considerably more power in the process. In this question, I am looking at how the teacher constructs lessons 'linguistically' (i.e., the linguistic resources he utilises); discursively (i.e., the identities, objectives and norms of behaviour which constitute distinct 'speech events'); and ideologically (i.e., the ways in which this teacher's linguistic and discursive construction of lessons is linked, interdiscursively, with wider social relationships and processes). My primary concern is to build an 'emic' picture of 'what is going on here?' based on the internal logic of interaction, i.e., the ways in which 'contextualisation cues' are used to signal, construct and negotiate distinct 'speech events', or lesson activities and the discursive characteristics of these activities. This concern is a response to what I consider to be a lack of curiosity by researchers about teachers' construction of lessons, which tend to be regarded as problems to be replaced and transformed with alternative pedagogies, rather than resources to learn from and build upon. This reflects my commitment to 'positive critique' (Fairclough, 2013) i.e., to learn how this teacher mitigates the negative impact of EMI, and responds to the challenge of the CBC, within the social and material context of this classroom and how he and other teachers can be supported in this endeavour. I provide 'negative critique' regarding the ways in which EMI constrains classroom communication in chapter 8, and propose practical interventions for teacher CPD in chapter 10.

In answer to the first research question, overall, I find that the teacher constructs these lessons purposefully with students, to achieve particular mathematical-pedagogical objectives in the context of this classroom; using a range of multimodal and multilingual semiotic resources; and through performing established routines and by responding to students.

I illustrate these claims in this chapter using extracts from a single instructional unit (5.7.2), which I name 'frequency polygon' after its mathematical focus. I use a single instructional unit, rather than extracts from several units, to show how distinct 'speech events'/activities function as a pedagogical whole. This reflects my ethnographic commitment to make sense of these lessons emically, before conducting etic, critical analysis (3.2, 5.1). The instructional unit presented here, like all units across lessons, is comprised of distinct 'speech events' which I term 'activities' (Lemke, 1990)(5.7.2). Each activity is named to reflect its pedagogical function as part of the instructional unit from the perspective of the teacher. The activities in this instructional unit are: preparation, presentation, demonstration and summary. These four activities are integral to, and present in, all instructional units across the data set (*Table 3*). As a result, this particular instructional unit is, to some extent, 'typical' of the wider data set and indicative of the teacher's pedagogical approach across lessons (Blommaert & Dong, 2010).

The chapter is structured into four sections, one for each of the four activities (i.e., preparation, presentation, demonstration and summary). In each section, I present my analysis alongside transcript extracts (5.7.1) and, where relevant, teacher interview data (5.6.2, 5.6.3). I discuss the distinct features of each activity, their function as part of instructional unit, and their relation to my claims. I indent transcript extracts to distinguish them from my commentary and analysis. I distinguish description of behaviour from verbal utterances in the transcripts extracts by further indenting verbal turns. I use line referencing to indicate the location of extracts in the instructional unit, and provide the full transcript in Appendix D. Transcript conventions are discussed in section 5.7.1, and a full list of conventions is included at the start of this thesis. In the chapter summary, I reflect upon how this unit works as a pedagogical whole and in relation to the three main claims that, the teacher constructs these lessons purposefully with students, to achieve particular mathematical-pedagogical objectives in the context of this classroom; using a range of multimodal and multilingual semiotic resources; and through performing established routines and by responding to students.

6.1.1 Introduction to this instructional unit

The mathematical focus of this instructional unit is 'frequency polygon', which is a form of line graph created from a bar-chart, used to represent frequency across a series. In this instructional unit, the teacher constructs a frequency polygon with students, multimodally, and by moving between general concepts and particular examples. This pedagogical approach is, I suggest, appropriate given the multimodal nature of mathematics (O'Halloran, 1998, 2015). The example which the teacher uses in this lesson is taken from the senior one mathematics coursebook which the teacher uses in all lessons (pages reproduced in Appendix E). The example is presented as a word problem, and is written on the board by the teacher at the start of the lesson:

> A group of 50 students take a test, with marks out of 10. The table shows the students' results by mark. i.e., how many students got 1,2,3,4 marks etc.
>
> (*Figure 4*, below)

In this lesson, the frequency polygon is used to show the number of students who got one mark, two marks, three marks and so on. At the start of the lesson, this information is presented in a table, which is called a frequency table in this context. In the course of the lesson, the teacher guides students to plot the frequency data from the table onto a bar-chart, called a histogram in this context, where frequency is represented on the Y axis. Once the histogram is complete, the teacher marks the middle of the top line of each rectangle on the graph, which he terms the midpoint. Finally, he draws a line between the mid-points to make the frequency polygon, which he names for students in spoken and written verbal language.

The recording indicates that all students in this lesson have a notebook and pen or pencil. Six coursebooks, including the teacher's, are visible in this lesson.

Table 10 below, presents the four activities which comprise the instructional unit, the time for each activity and for the unit overall.

Activity	**Time**
Preparation	3 minutes and 22 seconds
Presentation	3 minutes and 8 seconds
Demonstration	9 minutes 29 seconds
Summary	1 minute 19 seconds
Total time	16 minutes 8 seconds

Table 10 Frequency polygon activities and times

6.2 Preparation

This instructional unit, like all instructional units in the data-set, begins with the activity which I call 'preparation', in which the teacher and students write texts, on the blackboard and in their notebooks respectively, to use in the lesson. This routine start to instructional units differs from the student-led and talk-based approach in the textbook, which is written 'as if' students can read it directly, alone or in small groups (see, textbook pages, Appendix 5). The intended approach of the textbook is precluded by the limited number of textbooks in these lessons (Early & Norton, 2014; van de Kuilen et al., 2020) and the fact that it is written in 'English only' which mean that most students are unable to access the textbook without mediation from the teacher (Milligan et al., 2016). The teacher writes text from the textbook onto the black-board, which the students copy into their notebooks, as illustrated in the extract below:

> The teacher is writing text on the board from the textbook, which he holds open in his left hand. He has divided the board into three roughly equal-sized sections with chalk lines, and is writing in the far-left section. He occasionally stops to check his work, or to look in the textbook. The students are seated. The majority write in their notebooks, looking periodically up at the board. Many students are also talking together and/or looking around the room. The teacher does not look at or talk to the students. At one point he makes the sound 'sss!' without turning around
>
> (Line 1)

The text which the teacher writes is reproduced in Figure 4, below:

8.5.6 Histogram and Frequency polygon

definition: a histogram is a diagram used to represent frequency distribution in an ungrouped data.

- a frequency polygon is a line graph drawn by joining all the mid point of the top of the bar of a histogram

example: table shows how a group of 50 students performed in a maths quiz marked out of ten

marks	1	2	3	4	5	6	7	8	9	10
f	2	2	11	11	12	7	4	1	0	0

a) Represent the information in a graph

b) draw a frequency polygon

Figure 4 Frequency polygon board-work

The text that the teacher writes (Figure 4) is indicative of the multimodal nature of mathematics discourse (J. N. Moschkovich, 2015; O'Halloran, 2015) and includes various distinct mathematical registers (Schleppegrell, 2007). It begins with the dual *heading* 'histogram and frequency polygon', indicating the relationship between these two concepts. The heading is followed by *definitions* of histogram and frequency polygon. Underneath, an example exercise in the form of a *word problem* is presented. The verbal parts of the text are entirely in 'English', and English is the only verbal language written on the board in these lessons, and in student notebooks (*Table 3*), (Setati et al., 2008, p. 16). The 'English' text includes various aspects of mathematics register (i.e., headings, definitions and word problems) along with other semiotic forms (i.e., the table and numbers) to make a 'whole' composite text (J. N. Moschkovich, 2015; O'Halloran, 2015; Schleppegrell, 2007).

The text that the teacher writes (Figure 4) is taken from textbook (Appendix E), but is substantially different from the texts as they are presented in there. The teacher begins his text using the heading '8.5.6 Histogram and frequency polygon', which is the same as the start of the textbook unit. However, he removes the activity that follows the heading in the textbook (Appendix E, activity 8.24 in the blue box, p.221). The activity asks students to work in groups and, using dictionaries and the internet, to find definitions for the two terms, 'frequency polygon' and 'histogram'. They are to consider the differences between the definitions from these two sources, and other possible sources for such definitions. Finally, students are asked to 'distinguish between a histogram and a bar graph' (ibid.). The textbook activity is intended to be student-led and talk-based, and apparently aims to build 'generic' competences of collaboration and accessing information, in addition to constructing mathematical knowledge. As such, the textbook is aligned with the approach of the competence-based curriculum (REB, 2015), 2.3.2, and 'constructivist pedagogy' (Chisholme & Leyendecker, 2008). Instead of the 'learner-centred' textbook activity, under the heading '8.5.6 Histogram and frequency polygon', the teacher copies definitions for a histogram and a frequency polygon. He takes these definitions from a later section of the coursebook where they appear in a yellow text-box headed 'learning point' (p.221, Appendix E), and are, presumably, intended as a conclusion for the groupwork activity. In contrast to the sequence presented in the coursebook, the teacher uses the definitions as the starting point for this pedagogical unit in which doing and seeing mathematics form the main pedagogical activity.

It is striking that, contrary to suggested 'best practice' (Probyn, 2015; Setati et al., 2002) and the lessons presented in the textbook, the teacher begins these lessons with academic written text in English. On one level, as I suggested above, this can be seen as the teachers' pragmatic response to limitations in this classroom: the lack of textbooks, and students' limited English in relation to the linguistic demands of the textbook. However, and in addition, it reflects this teachers' purposeful pedagogical approach, which centres around engaging students in mathematics through presenting mathematical texts and demonstrating mathematical examples, with students. The teacher's approach is apparent through the text that he constructs on the board during preparation, the activities he constructs in lessons, and the concise way he expresses lesson objectives after lessons (06.13; 06.27; 09.17; 09.19 TIT, 5.6.2).

The teacher's preference for showing rather than talking mathematics is further evident in his removal of the second sentence of the histogram definition, which is: "A histogram resembles a bar graph or bar chart with the bars touching one another" (Appendix E, yellow box 'learning point', p.221). It may be that he considers the descriptive statement superfluous, given that students will see a histogram in the course of the lesson (6.3 and 6.4). The teacher reproduces most of the 'example' (Appendix E, 'example 8.16' in a pink text-box, p.221), and his use of the example in this lesson and across lessons is central to his pedagogical approach. In post lesson interviews the teacher and student describe the value of using relevant examples in lessons (06.13.TIT; 09.19.TIT; 09.17. SGIT, SFG; 09.19., 5.6.2). For example:

> I: when you are teaching, how do you know that this part is very important and the other one is not that much?
>
> T: when you see that students like, when the part is relevant to them.
>
> (06.13.TIT)

Preparation is a well-practiced routine activity, which is evident in the way students 'play their role', copying the texts from the board into their notebooks without verbal instruction from the teacher. The activity is co-constructed by the teacher and students, although there is no visible interaction between them. The fact that the students play their role without questioning the teacher, suggests they are aware of the function of the activity. Moreover, the routine nature of this activity precludes the need for verbal instructions and is, therefore, time-efficient and effectively constructed using non-verbal semiotic resources (Barrett, 2007, p. 286; Bernstein, 1996, p. 49). The lack of teacher and student interaction indicates there is little pedagogical value in this activity (Vygotsky, 1978). I suggest that, at this point in the lesson, the teacher does not intend to help students understand. The activity is an important precursor to more responsive pedagogical interactions which occur later in the lesson (6.3, 6.4, 6.5). That said, even in this activity the teacher responds to students, providing 'language support' (1.2) as he simplifies the language of the textbook in the text he writes on the board. In the textbook the two tasks following the example are written as follows:

> (a) Using a suitable scale, say vertical scale 2cm: 4 units and horizontal scale. 1cm:1unit, represent this information on a histogram.
>
> (b) On the same graph, draw a frequency polygon.
>
> (Appendix E, p.221)

In contrast, on the board, the teacher writes:

> a) Represent the information in a graph

b) draw a frequency polygon

Thus, we see the teacher mediating the textbook for students in a way that makes the English, and the mathematics accessible to them. In this first activity, the central elements of this teacher's construction of lessons are apparent. Firstly, I pointed out the multimodal form of the text that the teacher wrote on the board which is reflected in the teacher's pedagogical emphasis on showing and doing mathematics, in addition to talking mathematically. Secondly, I highlighted the ways in which the text that the teacher constructs demonstrate his purposeful construction of lessons overall. The textbook unit begins with a student-led informal talk-based task which reflects a widely accepted 'ideal' pedagogical model (Probyn, 2015; REB, 2015; Setati et al., 2002). In contrast, the teacher's approach, which centres on showing students mathematics through demonstrating examples, begins with writing formal mathematical texts. This has limited pedagogical in itself, but is an important precursor to the collaborative construction of mathematical activity later in the lesson. The teacher's approach is markedly different from the 'pedagogical ideal' of the textbook, but resonates with the view of learning as participation in classroom mathematical practice and apprenticeship learning (3.3.3). Moreover, it reflects the teacher's interaction with several aspects of classroom context including his perception of students needs and abilities; resource and time constraints; and the language in education and curriculum policy (3.3.2). However, it is insufficient and unhelpful to see these lessons only as a response to contextual limitations, or as lacking in relation to the pedagogical approach of the textbook. Finally, I indicated the ways in which this activity is a routine constructed by the teacher, with students, in a way that is responsive to students and the context of the lesson.

> Once he has finished writing, the teacher steps back and checks the text that he has written. After this, he returns to the board
>
> (Line 1).

It is at this point that presentation begins. In total, this activity lasts for 3 minutes and 22 seconds.

6.3 Presentation

In this second activity, which I term 'presentation', we see the teacher at the board, chalk in hand, reading sections of the text aloud to students. On the surface, this looks like classic "chalk and talk" (Uworwabayeho, 2009). However, the teacher's behaviour in this activity, and the fit between this and later activities, indicates there is more going on.

> The teacher moves towards the board as he talks. He traces his chalk along the 'definition' of a histogram as he says:
>
> > We are going to see what is a histogram …
>
> (Line 3)

The teacher signals the start of the 'main lesson' multimodally, by moving towards the board and indicating the text on the board with his chalk as he talks. He tells students they are going 'to *see* what is a histogram' (my italics) and makes the link explicit by touching the board as he talks. With the pronoun 'we' it seems that the teacher aligns himself with the students, as members of a community of practice (Barrett & Bainton, 2016; Lave & Wenger, 1991; J. Moschkovich, 2002) engaged in mathematical activity. This impression is reinforced non-verbally by the teacher's behaviour, which suggests that he is 'reading aloud' the text on the board *with* students. He never fully faces the class, but remains focused on the text, underlining key words and phrases as he continues:

> He takes a step back, glances at the class, then turns again to face the board, saying:
>
> > A histogram .. is a diagram used to represent … the frequency on a graph …
>
> He steps towards the board with his right hand, holding the chalk, raised. He underlines the phrase 'make a line' as he says:
>
> > and we make a line.
>
> Then he steps back to the side of the board. He is three quarters turned towards the board, as he continues:
>
> > In frequency a polygon is a line …. join all all the frequency on the on the graph
>
> (Lines 4-6)

The teacher's position during lines 4-6 can be seen in

Figure 5, below:

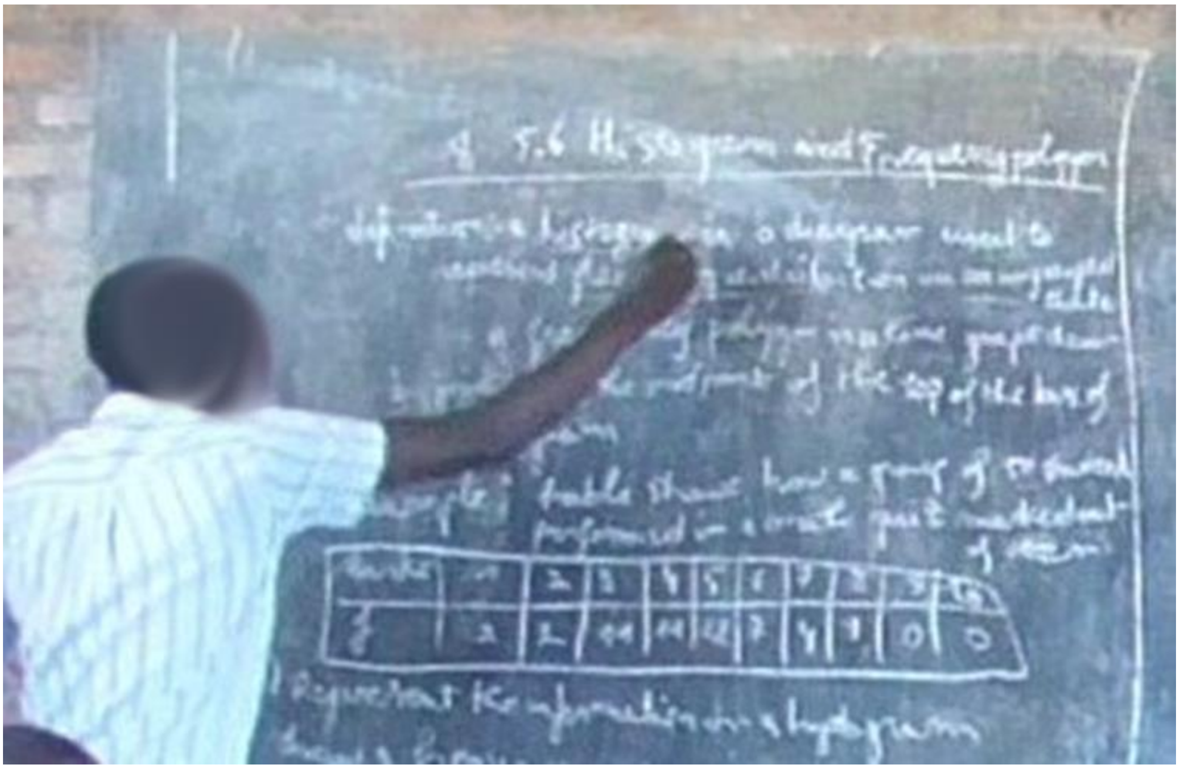


Figure 5 The teacher underlines text as he reads aloud

The teacher's body language indicates to students that he is 'reading aloud' from the text on the board. His purpose here appears to be to show students the text, as if they are reading the text together. At the same time, the teacher makes the text accessible to students. He does this through the raised volume of his voice, which is intended for the class to hear; by touching and underlining key sections of the text; and by paraphrasing the dense, academic text on the board into simpler English. Compare for example the teacher's statement in line 6:

> A frequency a polygon is a line …. join all all the frequency on the on the graph

With the sentence which is written on the board

- a frequency polygon is <u>a line</u> graph drawn by joining all the mid point of the top of the bar of a histogram (*Figure 4*, above).

It appears that, at this point in the lesson, the teacher's aim is to present the text, and draw students' attention to key words and phrases, as the basis for the main pedagogical activity of the lesson which follows (6.4). As noted above (6.2), this teacher's pedagogical approach contrasts with widely-accepted pedagogical models, which recommended that 'presentation' of formal text follows the verbal exploration of new concepts, often in groups (Probyn, 2015; REB, 2015; Setati et al., 2002). Nevertheless, it 'makes sense' as part of this lesson.

The teacher continues the performance of doing the exercise *with* students.

> In the three second pause after the teacher says ‘graph’ he walks towards the middle section of the board with his right hand, holding the chalk, raised. He continues talking to students, now fully facing the text on the board:
>
> > as you are going to see in this .. example ……..
>
> As he talks, he writes and underlines the word ‘Solution’ at the top of the middle section of the board
>
> (Lines 7-8)

In the sequence that follows, he ‘shows’ students how to draw and label a histogram, as he draws the graph on the board. He engages students in the process, using question forms which are apparently intended to gain, direct and maintain their attention rather than assess their comprehension.

> The teacher turns to look at the table that he drew on the left of the board. After a few seconds he turns back to the middle of the board and draws the outline of an X and Y axis in long single strokes. As he finishes the second, horizontal line, he says:
>
> > frequency located on? …
>
> In the three second pause, he glances to the left at the table, and then raises his chalk to the vertical y axis as he says:
>
> > the y axis ….
>
> In the four second pause, he writes the word ‘frequency’ along the Y axis.
>
> (Line 9)

The teacher appears to be using the question form be to draw students’ attention to his action i.e., where to plot frequency on a histogram, rather than to check their understanding, because he does not repeat the cue for an answer but continues drawing the graph.

> Then, he lowers his arm, and looks down to the X axis, where he adds numbers, as he says:
>
> > and ….. the marks …….
>
> He rubs out the X axis line with his hand and redraws it. He steps back, and looks at the table on the left third of the board for five seconds, then turns back to the graph. Over ten seconds, he numbers points along the X axis, extending the horizontal line once. As he does this, he says quietly, as if to himself:

> *four…six…seven…nine……*Ten …..

> He speaks the last number, 'ten …..', aloud. In the pause that follows, he takes three steps back, looking at the table on the left and facing the board. He pauses a second, and then raises his chalk and begins to label the Y axis.
>
> (Lines 10-11)

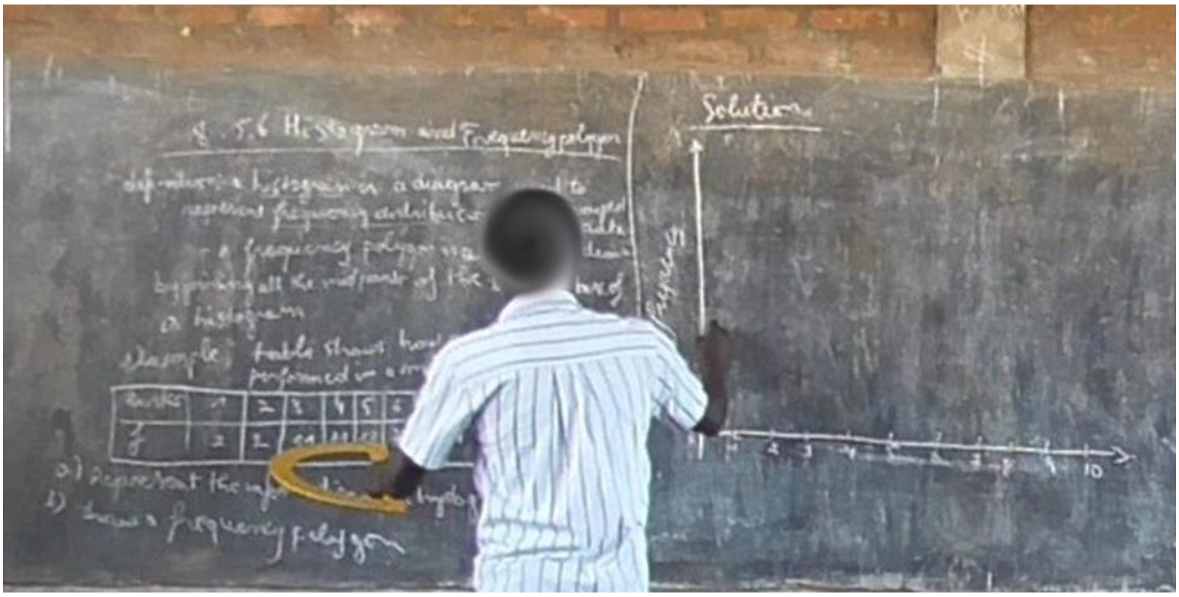


Figure 6 The teacher shows students how to draw a histogram

Figure 6, above, shows the teacher plotting numbers from the table onto the graph by moving the large protractor, which he uses as a ruler in this lesson, between the table and the graph. The teacher's over-sized and deliberate gestures indicate that he intends to show students how he identifies the numbers to plot on the two axes from the table and how he draws, checks and redraws the axis lines. In the next sequence, the teacher resumes a more actively pedagogical stance as he engages students, multimodally, with the meaning of the term 'ascending order'. The teacher seems to signal a shift to 'teaching', by taking a step away from the board and turning so that he is half-facing the class.

> The teacher points to the table drawn on the left side of the board with the protractor. He holds the protractor in his left hand, and half-turns to the class. He looks up towards the class as he finishes talking.
>
> > If you write the frequency …
>
> As he talks, he shifts the protractor into his left hand and traces it along the second row of the table, stepping towards the middle of the board as he does so. When the teacher comes to the end of the table, he pauses and says:

> > we write on ? ..
>
> He waits for two seconds, extends his left arm to the right and points to the bottom of the y axis with protractor and says:
>
> > ascending order
>
> At the same time, he moves the protractor from the bottom to the top of the Y axis. He pauses for a second, looks up and says:
>
> > Sibyo? *(Isn't it?)* …..
>
> He waits for a further second, then turns back to the table on the left of the board, pointing to it with the protractor. He stands like this for three seconds, then turns back to continue labelling the Y axis, saying:
>
> > from the lowest to the highest number ……………………………..…… (50 seconds)
>
> As he speaks, and in the 50 second pause the follows, he labels the Y axis slowly and deliberately. As he works, he looks over to the table and pointing to and between particular cells with the protractor. For five seconds after he finishes labelling, he continues to look at the graph, and then at the table, as he takes three steps back towards the door. His gaze is directed at the table which he touches with protractor which he holds in his left hand.
>
> (Lines 13-16)

This second activity is typical of other examples of 'presentation' in this data set (*Table 3*) in that the teacher uses the activity to tell students the mathematical objectives of the lesson, and to present and the mathematical texts they will use. In this activity, the teacher positions himself *with* students, as colleagues, reading the text aloud and following the instructions to prepare the graph on the board for use in the next activity. Interaction with students is limited, I suggest because the teacher's intention is to *show* students the mathematical texts, which they will use in the next activity rather than check their understanding. That said, at times, he shifts into a more explicitly pedagogical mode, paraphrasing the term 'ascending order' and using gesture to indicate meaning. As I noted in section 6.2, above, the teacher's construction of this activity *with* students differs significantly from the textbook, where the intended activity (Appendix E, activity 8.16, p.221), is for students to draw a histogram in groups or individually. The teacher's approach aligns with his practice of *showing* students mathematics, evident across lessons. Further, it appears to be a means to save time for what he considers the pedagogical core of the lesson. The strategy makes sense, given the limited number of textbooks in the classroom, and the language policy which make textbooks hard for students to access independently. This activity is a precursor to the pedagogical core of this teacher's approach, which we see in the next activity: 'demonstration'. In total, this activity lasts 3 minutes and 8 seconds.

6.4 Demonstration

Next, I consider the third activity in this pedagogical unit: 'demonstration', which is, I suggest, the pedagogical core of this lesson and these lessons in general. The importance of this activity, for the teacher, is evident in time he allows for the activity compared to other activities in instructional units (*Table 3*). In this instructional unit demonstration lasts longer than the other three activities combined (see *Table 10*, above). In this section, I discuss the activity in relation to my claims using two extracts, from the beginning and end of the activity.

In demonstration, the teacher invites students to volunteer to complete an exercise on the board. The purpose of the activity is to show the class how to do the exercise, which contextualises the mathematical concept that is the focus of the lesson (in this case, frequency polygon). In interview, the teacher relates this activity to the CBC and describes students learning through "being active" and "helping each other" (Fieldnotes, 04.06; 8.2). Notably, he does not talk about his key role in enabling the student at the board to complete the exercise, and engaging the other students in the task as this is not part of CBC discourse (van de Kuilen et al., 2020). As the extracts in this section illustrate, the teacher constructs this activity with students, using multilingual and multimodal semiotic resources, through routines and by responding to students. The activity begins with a familiar routine, in which the teacher asks for and nominates a volunteer using verbal and non-verbal semiotic resources:

> The teacher lowers his protractor and steps away from the board. He raises his eyes to the class, and steps towards the middle of the room as he says:
>
> > Who can come .. to make ..
>
> He steps to the board and retraces the second vertical line of the table with the chalk as he completes his invitation:
>
> > a frequency polygon…
>
> He looks up towards the seated students, and holds the chalk out towards the class in his right hand which is raised to shoulder height.

(Lines 17-18)

The teacher signals the beginning of this familiar activity, using the routine question ‘who can come?’ combined with the gesture of offering the chalk to the class. In contrast to the teacher’s questions in the previous activity, the question is ‘genuine’, in that the teacher waits for a response from students before he continues. Indeed, as we see next, students’ non-response is meaningful and the teacher responds to it, initially be rephrasing the question.

He pauses in this position, then asks:

Anyone to try…Hmm? Ntawaza ngo agerageze (*Who can try)*

(Line 19)

The teacher emphasises his invitation, firstly using English, then with a pause, then by saying ‘hmm?’ with rising intonation and then in Kinyarwanda. The teacher’s body language is shown in *Figure 7*, below:

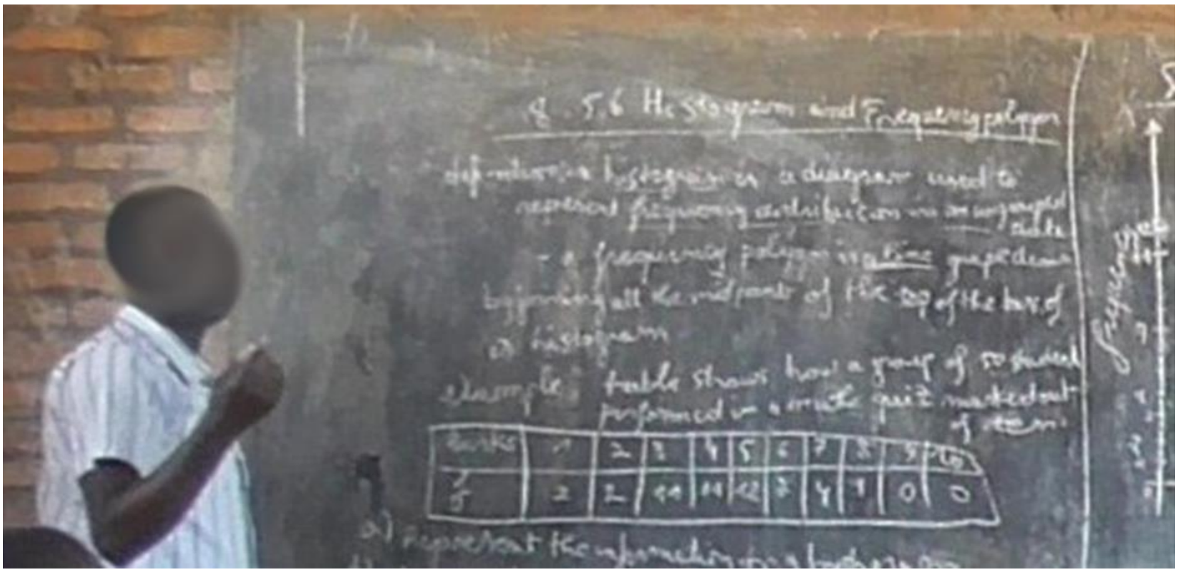


Figure 7 The teacher invites a volunteer

This purposeful ‘switch’ between ‘languages’ (3.3.1), is used by the teacher to emphasise and repeat the invitation, rather than to help students access meaning. The meaning is clear to students, presumably, because of their familiarity with the activity, and the teacher’s use of gaze and gesture alongside speech (see *Figure 7*, above). What we see here, therefore, is the teacher drawing on a multilingual and multimodal repertoire to set up this activity. In addition, we see students participating in a way that drives the interaction, through the linguistic cue of non-response.

> The teacher moves his gaze around the room in the ten second pause that follows. There is no visible or audible response from students. Most continue to look at the board and write in their notebooks.
>
> (Line 20)

The teacher interprets the students' non-response as a sign that they need additional explanation, before demonstration can begin and responds by providing additional information about the task, verbally and non-verbally.

> The teacher moves towards the middle of the board, pointing to the graph with the protractor which he holds in his left hand so that he is half facing the class. He says:
>
> > Iushyize izi data kuri graph ugashushanya ya polygon twabonye (*We use the data for the graph to draw the polygon we have seen)*
>
> (Line 21)

In this utterance, the teacher 'meshes' mathematical English and Kinyarwanda, and uses gesture and the graph on the board to help students understand the task. Here, I suggest, he is using language as a transparent resource (Adler, 1999; Setati et al., 2008) to enable students to access mathematical meaning, whilst using English for mathematical terms. In this way he provides access to mathematics and English (Setati et al., 2008). It is apparently effective, as a student volunteers immediately. Over the next twelve seconds the student's bid is accepted by the teacher, and the student moves to the front and begins his turn.

> A student seated at the back right of the room raises his arm and clicks his fingers. The teacher looks up, and signals with the chalk to a student at the back who has volunteered. the boy stands and moves towards the front. The teacher points to different cells of the table as the boy comes forward. The student moves towards the teacher. He lifts his hand to receive the chalk, which the teacher gives him.
>
> (Line 22)

This interaction is constructed non-verbally, which indicates students are familiar with the activity. It is notable that the teacher constructs this activity to be led by the volunteer. This is evident as the student moves to central position in front of the board, and takes the chalk from the teacher, who moves to stand at the side.

> As the teacher hands the chalk over, he says:

> You start from zero
>
> (Line 23)

This exchange of the chalk, and the instruction from the teacher, signals the beginning of the student's turn. In the 44 seconds which follow, there is no verbal exchange between the teacher and student. In this time, the teacher shows the student that he wants him to use the protractor (used as a ruler in this lesson), by holding the protractor towards him, which the student rejects. The student begins the task. He initially draws faint dotted lines as if he is uncertain. He looks at the teacher, and following eye contact with the teacher proceeds to draw full lines as if he has received confirmation.

> The teacher hands the protractor to the student, then picks up his copy of the textbook from a desk on the left side of the room and stands to the side. The student puts the protractor down on the same desk at the front left, then glances towards the teacher. The student stands to the left of the board, and glances between the table on the left and the chart. He begins to mark dots on the chart, outlining bar shapes. He turns to look at the teacher. He then draws over the dots as a thick line. He turns to the table, and points with his finger to the second column, then begins to draw it on the graph.
>
> (Line 24)

In addition to the fact that this exchange is constructed non-verbally, it is notable that it is the student who solicited the teacher's support, and the teacher who responded. The moment when the student looks towards the teacher is shown in *Figure 8*, below:

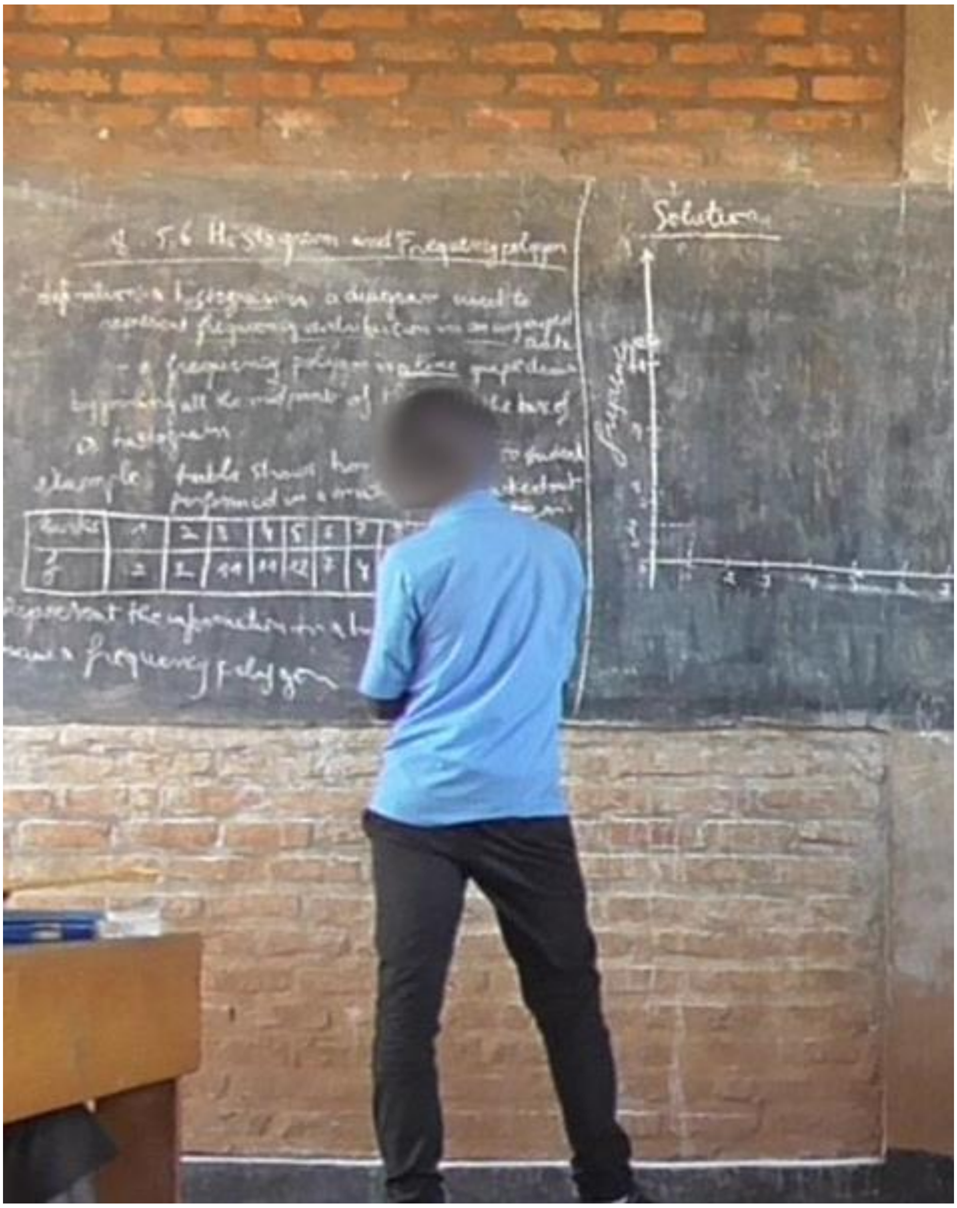


Figure 8 The student checks with the teacher

> As a result of looking again at the student, the teacher notices that the student is not using the protractor. It is at this point he speaks:
>
> > using this ruler …
>
> The teacher steps forward, puts his book down on the desk and hands the protractor to the student. The student takes it and uses it as he begins to draw the lines for the second bar on the chart.
>
> (Line 25)

The teacher remains close to the student and guides his work, verbally and by gesturing to the frequency table on the board:

The teacher stands to the left of the board, near the frequency table. He points to the second column of the table as he talks first very quietly and then louder. The volunteer looks towards the teacher as he starts talking, and drops the protractor as the teacher's volume increases. The teacher lowers his voice then takes a step back.

for this .. this .. the student who has two ... are two …ok ……..

(Line 26)

The teacher's raised voice, which seems to startle the student at the board, is intended to make the exchange accessible to the other students in the class. The teacher is at once helping this student to do the activity, and making the activity and the 'scaffolds' he provides (3.3.2), accessible to the rest of the class. *Figure 9*, below, shows the teacher guiding the student at the board in a way that is accessible to the class:

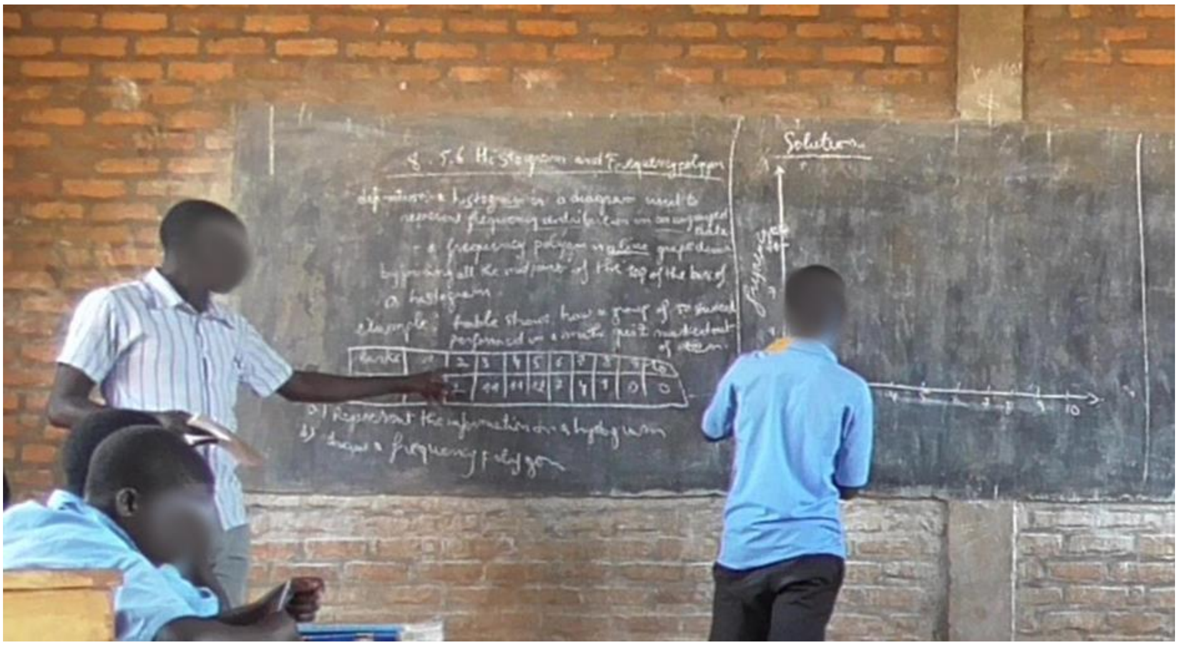


Figure 9 The teacher guides the student at the board

The student finishes drawing the second bar. He looks at the frequency table, then back at the teacher. He gestures with his right arm extended to the graph.

(Line 26)

The student requests further support from the teacher, by gesturing towards the graph. This moment can be seen in *Figure 10*, below:

Figure 10 The student requests help

The teacher who has been watching closely responds immediately, in a way that is audible to the class:

> The teacher speaks slowly and clearly:
>
> > student who has three are? eleven …..
>
> The volunteer responds by raising the protractor and beginning to draw the third column.
>
> (Line 27)

The activity of demonstration is central to this teacher's pedagogical approach of showing the class mathematics exercises, examples and concepts using a multilingual and multimodal semiotic repertoire. More specifically, as we see here, his strategy, which is evident across lessons, is to guide a volunteer to show their classmates. As a result, the class potentially see the task being performed and see and hear the scaffolds which the teacher provides. The teacher constructs this as a student-led activity, and the guidance he provides is in *response* to the student. This is arguably more efficient than providing a lengthy verbal explanation before the task. The teacher's interventions are limited and targeted. Moreover, the seated students see the performance of the task and the verbal and non-verbal scaffolds from the teacher, which may be more meaningful than a de-contextualised verbal explanation (Brown et al., 1989; J. N. Moschkovich, 2015).

Next, we shift to the end of the activity, 4 minutes and 23 seconds later. In the interim period the student volunteer has continued to complete the graph, with occasional guidance from the teacher. At this point, the teacher stands to the side of the room with the textbook open in front of him and shifts his gaze between the coursebook and the student at the board. It is clear that the teacher is still paying close attention to the student at the board, because he is quick to respond when the student signals for support.

> The student stops working and looks at the table on the left and then the chart. The teacher looks up, then walks towards the student at the board first without talking, and then saying quietly:
>
> > *..Uhm! Tugeze kuri element ya kangahe? (We are on which element?)*
>
> (Line 54)

The low volume of the teacher's voice indicates that he intends only the student volunteer to hear. The volunteer indicates to the teacher where he is at in the exercise. The teacher shows the student how to continue:

> The teacher stands to the right of the student. The student raises the protractor and gestures to the graph, then across to the table and back to the graph. The teacher picks a board cloth up from the floor, he makes a questioning sound:
>
> > *..Umh? .....*
>
> Then student makes a mark with his chalk on the X axis. The teacher wipes the line off the board up to the point the student has marked. The teacher steps back, then traces along the X axis with his finger. As he does this, he steps to the right and says, quietly:
>
> > *Komeza uzane hino. Ugeze aha (Continue until here) ………. (10 seconds)*
>
> For the next ten seconds he stands about a metre away from the student, looking towards him. In this time, the student redraws the X axis, then steps to his left and looks towards the table of information.
>
> (Lines 54-6)

It appears at this point that the teacher wants to engage the rest of the class, and bring the activity to an end. He does this by engaging the seated students verbally, using Kinyarwanda, to identify the figure which the student volunteer should plot on the graph:

The teacher walks over to the left of the board. As he passes behind the student volunteer he says, aloud:

Karindwi afite mo kangahe? *(Seven occurs how many times?)*

The teacher points to the table of information as he passes it, then stands half facing the student and half facing the class. As he touches the table he says:

Ariko ko mutamubwira ibyo yandika *(Please tell him what to write.)*

(Line 57)

A number of seated students look up towards the student working at the board, and several begin to call out answers.

Several students call out the answer to the teacher's question (seven has?), immediately after the teacher has finished speaking and intermittently in the ten second pause that follows.

Kane *(four)* Four Kane (four) Kane (four) Four Kane (four)

The teacher stands to the left of the board. For the first five seconds he faces the student, then he turns to face the back of the room and repeats the question:

Karindwi has? *(seven has?)*

Again, several students answer almost immediately:

Four. Four. Four …………….

The student working at the board continues drawing neat and careful lines.

(Lines 58-60)

The teacher has engaged the class in 'correcting' the student at the board (Westbrook & Croft, 2015) and provided the student at the board with the information he needed to complete the example for the class. After 15 seconds the teacher resumes with another question for the seated students:

Noneho umunane se wo ufite kangahe? *(What about eight?)*

Several students answer, but their responses are indistinct. Most students are now copying the graph from the board. The teacher remains at the far-left of the room, looking through

> the student book. The volunteer at the board completes the sixth bar, then looks over to the table again. There is a silence of two seconds, then two students call out:
>
> > Rimwe Rimwe *(one one)* ………………………. (30 seconds)
>
> In the pause that follows the teacher remains at the far-left of the room, looking through the student book. The volunteer at the board completes the eighth bar, then looks over to the table again.
>
> (Lines 61-2)

Finally, the teacher ends the activity, by providing the last two figures himself, taking back central position in the room and taking the chalk back from the student.

> The teacher looks up from his book at the student volunteer. He says:
>
> > Icumi ho ifite zero ….. *(Ten has a frequency zero)*
>
> Then he moves towards the board, facing the student who looks up towards him. As he moves, he continues talking:
>
> > Ababonye icyenda nta n'umwe. N'icumi nta n'umwe…. (Nine also has a frequency zero. Ten is zero).
>
> The teacher arrives by the student as he finishes talking. He extends his right arm, and the student gives him the chalk. The teacher takes the chalk from the student volunteer, and completes the final values on the graph, which are for the students who got nine and ten marks (both zero).
>
> (Line 63-64)

The teacher brings the activity to an end by retaking central position in the room, taking the chalk from the student volunteer and completing the task. The teacher does not verbally state that the activity is over, indicating that the students are familiar with this routine.

In this section, I have provided an example of the activity I term 'demonstration', the pedagogical core of these lessons. The importance of the activity is evident in the time that the teacher allows for it. The teacher constructs this activity as student-led (and teacher managed), by asking for and nominating a student volunteer. The power that the students have in this activity is evident at the start when, through non-response, the students prompt the teacher to provide additional guidance. The idea of this activity, as the teacher describes in interview, is for the students to learn by helping each other by seeing an example performed by a fellow student (Fieldnotes, 04.06). The teacher shows students that he is marginal in this activity by standing at the side of the room and looking in the textbook. At the same time, he observes the student at the board closely, and provides additional guidance where needed. In this way the seated students see the exercise being performed, and the verbal and non-verbal task support from the teacher is also available to them. Towards the end of this activity the teacher uses Kinyarwanda, as a 'transparent' resource (Setati et al., 2008) to involve other students in assisting the student at the board to complete the task. This indicates that the teacher is aware of time constraints, and the need to keep other students in the room engaged. The teacher ends the activity by providing the final answers for the student at the board, and moving to the front and taking chalk back from the student volunteer. As in the previous two activities the teacher does not tell students what he is doing, indicating that this is a well-practiced routine. This activity is purposefully constructed by the teacher, multilingually and multimodally, through routines and in response to students.

6.5 Summary

The final activity in this pedagogical unit, I term 'summary'. In this activity the teacher concludes the mathematical exercise (in this case, drawing a frequency polygon) and makes explicit links to the text with which he began the lesson, bringing the pedagogical unit full circle. The teacher uses gaze, body language and a series of tag questions to construct this activity as a dialogue. He is not apparently looking for, and does not get, much verbal response from students. At most, one or two students respond to keep the dialogue going. Nevertheless, the dialogue has a pedagogical purpose: the aim is to attract, maintain and direct student attention to the process of completing the task, and to target mathematical terms and concepts. In this extract we see how the teacher 'meshes' English and Kinyarwanda, using language as a transparent resource with English mathematical terms, and thereby enabling students to access English and mathematics (Setati et al., 2008). As before, he consistently uses English for mathematical terms and pedagogical directives, often embedded in Kinyarwanda utterances indicating that his intention is to provide students access to mathematical terms, concepts and practices. He also uses non-verbal cues such as rising intonation and gaze, and the act of drawing the frequency polygon as part of his semiotic repertoire

The activity begins with the teacher gaining the attention of the class, as he completes the final two bars on the histogram. His back is to the class, and as he works, he calls for student attention:

> look here ……….

> Most students look towards the teacher. The student volunteer, on his way back to his seat, turns to look at the teacher over his shoulder. After eight seconds, the teacher turns and looks towards the seated students. He steps towards the graph, with his right hand (holding the chalk) raised to shoulder level, as he says:
>
> > Urabona izi rectangle.. (*Do you see these rectangles?)*
>
> When he says the word rectangle, he glances up to the class. Then, he turns back to the face board and says:
>
> > Are you looking for this?
>
> The teacher marks a point in the middle of the top line of 8th and 7th rectangles on the bar chart. His back is to the class, as he says:
>
> > Doo! murareba? *(Are you looking?)*
>
> He continues making points with the chalk on the top-middle line of each bar, from left to right, as he continues:
>
> > Hano ni midpoint of this rectangle. Sibyo? ..Muri kubireba? *(Here it is in the midpoint. Isn't it? Do you see that?)*
>
> As he says 'midpoint' he looks up towards the class. Otherwise, he faces the board as he continues to mark dots.
>
> (Line 65-7)

The teacher is directing students' attention to the process of marking the midpoints on each rectangle, verbally, and using gaze. One student responds to the teacher asking if they can 'see', and it is as if this single voice is representing the class.

> One student answers the teacher, quietly:
>
> > Yes ….
>
> (Line 68)

The response is apparently enough for the teacher to continue.

> Over the next four seconds, the teacher continues marking dots on the chart, after three seconds he glances down at the coursebook he is holding in his left hand his chalk still

poised on the chart. Then he turns back to the board and continues marking midpoints of the rectangles as he says:

Nitujoininga .. ..*(If we join)*

He steps to the side, so he is half-facing the class and continues:

izi point tugakora line *(these points with a line)*

He briefly looks up as he says 'point', and then turns back to the board as he completes his utterance. He glances down at his book, at the same time saying:

Sibyo? .. *(Isn't it?)*

(Line 69-70)

The phrase 'Nitujoininga' is hard to classify as either 'Kinyarwanda' or 'English'. It seems to be a 'mesh' of language, with the English mathematical term 'join' and the mathematical proposition 'if' in Kinyarwanda. In the line that follows he distinguishes the terms point and line. He gains and directs student attention through using English combined with looking up at students as he speaks. He continues directing students' attention to the mathematical process, and specific terms as he completes the frequency polygon:

He turns back to the board, and continues marking points, his right arm extended to head height as he says:

Muri kubireba? *(Do you see that?)*

A single student answers:

Yes ..

Then the teacher draws a line from the 'midpoint' of the third rectangle down to the second, then continues to talk and draw a line between the other midpoints:

Iyi line ijoininga midipointi … of this barchart. *(This joins the midpoints)* Niyo twita … *(We call it …)* frequency polygon .. do you understand..?

A few students answer.

yes..yes…

(Line 70-4)

In the 25 seconds that follow, the teacher finishes drawing the right side of the line. He steps back, then adds a mark to the left of the line. Then he steps to the left of the board and looks at the graph, before moving to the middle again. He draws a line from the frequency polygon and writes the label ‘frequency polygon’. This final action can be seen in *Figure 11*, below:

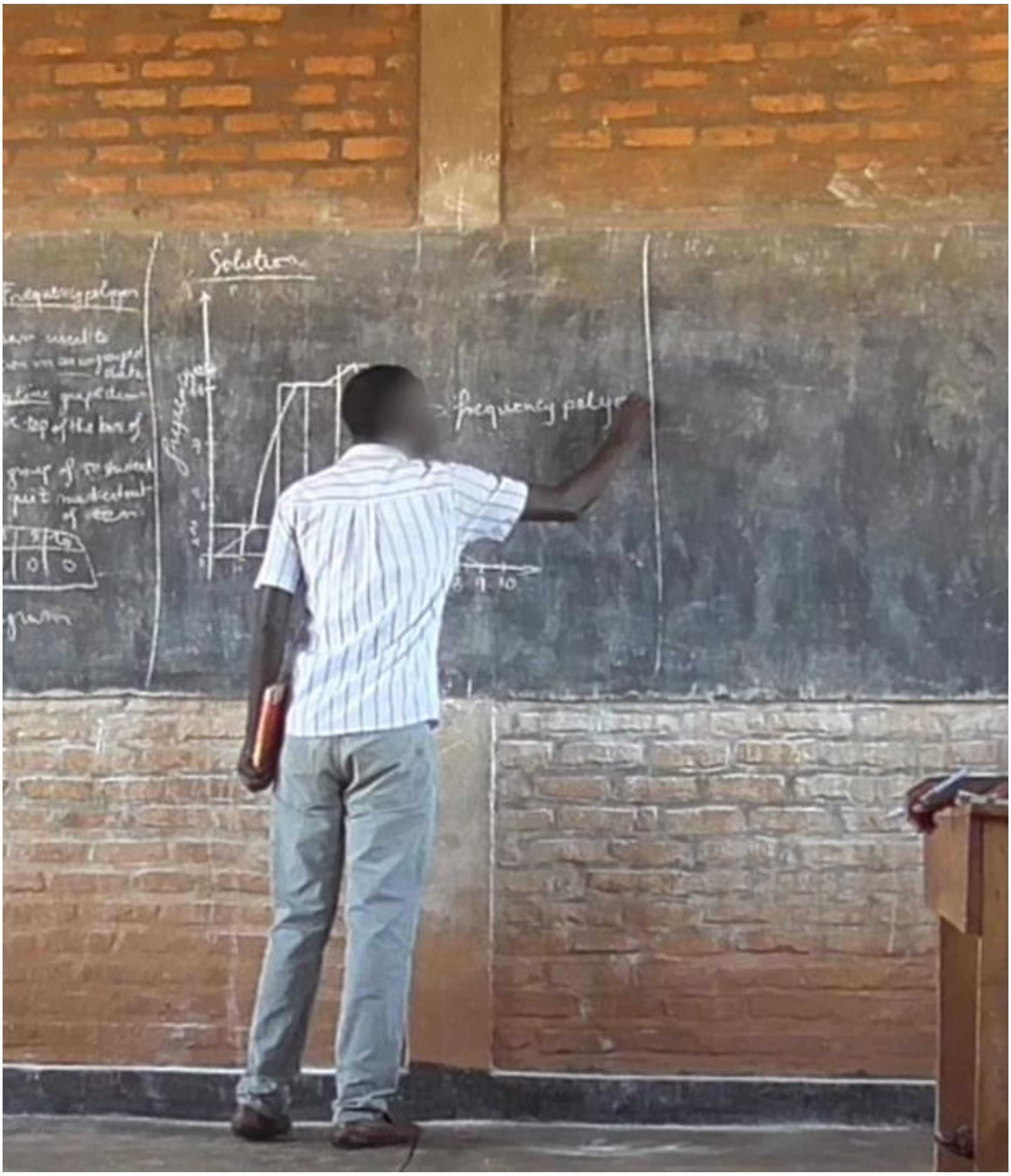


Figure 11 Teacher labels the frequency polygon

In this final activity, the teacher draws the midpoints and creates the frequency polygon. At the same time, he repeatedly calls for and directs student attention to what he is doing, and to the particular mathematical terms that he uses. He uses gaze, body language, question forms and intonation, and Kinyarwanda and English. He systematically uses English for mathematical terms, and this serves to make the terms visible to students. At times he 'switches' between English and Kinyarwanda, when calling for students' attention, using this as a device to get their attention. At other times he meshes 'languages', with English mathematical terms embedded in Kinyarwanda utterances, indicating his combined use of language as a transparent and visible resource to enable student access to language and mathematics (Setati et al., 2008). In addition, the teacher uses tag questions, 'switching' between English and Kinyarwanda, to gain, maintain and direct student attention (Probyn, 2009). The teacher completes the activity by labelling the graph 'frequency polygon', thus making a connection with the heading he wrote at the beginning of the unit.

In this unit of instruction, the teacher constructs a multimodal mathematical text with students and for students, which includes mathematical terms and definitions in English, a table, a histogram and a frequency polygon. He uses English mathematical terms and pedagogical directives as part of his multimodal repertoire. The main activity in this lesson, demonstration, is performed by a student volunteer, managed by the teacher and with support from the teacher and other students. The class see the performance of the example, and the scaffolds provided by the teacher, and provided support to the student at the board themselves, guided by the teacher. The focus in this pedagogical unit, and across pedagogical units is the mathematical practice and the mathematical text that is created through practice.

6.6 Chapter summary

In this chapter I presented a sequence of extracts from an instructional unit 'frequency polygon' to illustrate three claims about how this teacher constructs lessons: that the teacher constructs these lessons purposefully with students, to achieve particular mathematical-pedagogical objectives in the context of this classroom; using a range of multimodal and multilingual semiotic resources; and through performing established routines and by responding to students.

The teacher's construction of lessons differs from the mathematics lessons in the textbook, which typically begin with student-led talk-based tasks in groups (Appendix E), and reflect what is assumed to be an 'ideal' pedagogical approach (Chisholme & Leyendecker, 2008; Probyn, 2015; REB, 2015; Setati et al., 2002). In contrast, this teacher's lessons begin with written mathematical texts on the board, always in English (Setati et al., 2008) and centre around the construction of mathematical texts, forms and practices with students in whole-class interactions. On one level, the teacher's construction of lessons can be understood as a response to contextual limitations: the lack of textbooks (van de Kuilen et al., 2020), and students' limited English proficiency in relation to the language demands of the coursebook (Milligan et al., 2016). However, this is only part of the teacher's construction of these lessons, which I propose, indicate a 'whole' and purposeful pedagogical approach that is distinct from the textbook, but consistent with theoretical understandings of pedagogy (Vygotsky, 1978), and the multilingual teaching and learning of mathematics (3.3.3) (J. N. Moschkovich, 2015). The teacher's purposeful pedagogical approach is evident in his selection of texts from the textbook, his description of lesson activities and objectives during and after lessons, and the consistency of this approach across lessons in the data set (*Table 3*). The teacher's approach, of doing mathematics *with* students, resonates with the idea of induction in a community of practice and apprenticeship learning models of mathematics teaching and learning (Brown et al., 1989; Lave & Wenger, 1991; J. Moschkovich, 2002; J. N. Moschkovich, 2015). Further, it resonates with Moschkovich's recommendations for developing academic literacy in mathematics, through engaging students "simultaneously" in mathematical practices and discourses, using mathematical forms (2015, p. 44).

The teachers' flexible use of a range of multimodal semiotic resources to construct interactions, activities and mathematical discourses in these lessons, aligns with Garcia and Li's concept of translanguaging (2014); the multimodal nature of mathematics (O'Halloran, 2015) and reports from other multilingual classrooms in low-resource settings (Early & Norton, 2014). At times the teacher 'switches' between 'languages' to draw attention to mathematical terms and concepts, and to manage behaviour. He does so flexibly, often in response to students, and to help the understand (Probyn, 2009, p. 227; Setati et al., 2008, p. 16). He uses tag questions (e.g., 'sibyo?' (*isn't it?)* (line 13) to gain and direct student attention; and 'Kinyarwandised' English terms e.g., "Nitujoininga .. ..(If we join)" (line 69), practices described by Probyn (2009, p. 132). Probyn suggest that the use of 'Xhosalised' English is intended to reduce alienation (ibid.). Here I propose the term 'meshing' to describe the way in which this teacher uses 'transparent' Kinyarwanda and 'visible' English, within single utterances, to enable students access to mathematics *and* English in these lessons (Setati et al., 2008).

The teacher constructs lessons using the routines of familiar activities across lessons. This strategy saves the teacher time planning lessons, and during lessons by removing the need for lengthy verbal instructions (Barrett, 2007, p. 288; Bernstein, 1996, p. 49). At the same time, the teacher frequently observes students and assesses their participation, by looking at students and using tag questions. He responds to students, when he perceives they do not follow, often shifting modes (Barrett, 2007, p. 288). The teacher's responsiveness to students is most marked in 'demonstration', when the teacher literally and figuratively stands to the side, and observes and responds to a student working at the board. This teachers' use of demonstration as a purposeful pedagogical strategy echoes reports from Barrett (2007, p. 285), Early and Norton (2014, p. 682) and Westbrook and Croft (2015, p. 15).

It is not possible to know from the lesson recording how many students can follow or understand the content of the lesson, or would be able to draw or describe a histogram and frequency polygon as a result. The majority of students are seated a long way from the board and many may be unable to read the text, or may have difficulty hearing during lessons. Although, across focus groups, students talk about how the activities in these lessons help them to understand (06.13; 06.20; 06.27; 09.17;09.19 SFGT, *Table 7*), the students who volunteer for focus groups, like the students who volunteer to demonstrate in these lessons are likely to be those who understand the most of what is happening. It is likely that, as reported by Barrett (2007, p. 286), a number of students are ‘left behind’ in these lessons. I turn to the question of student participation in the next chapter.

7 How do students participate in these lessons?

7.1 Introduction

In this chapter, I present my answer to the second main research question: How do students participate in these lessons? My interest in student participation reflects my understanding that people learn, initially at least, through participation in social activity (Vygotsky, 1978), and a view of learning mathematics as participation in a community of practice (Lave & Wenger, 1991), through which students acquire “classroom-mathematical norms” (Moschkovich, 2002, p. 197)(3.3.3). Focusing on student participation and teacher and student interaction in these lessons, enables me to look beyond particular pedagogical modes (Barrett, 2007; Bernstein, 1996). Overall, I find that students participate multilingually and multimodally; in ways which are more and less controlled by the teacher; to co-construct and at times lead interactions and activities and to communicate mathematical meanings.

In this chapter, I illustrate these claims in relation to extracts from a single pedagogical unit which I name ‘surface area of cuboids’ after its mathematical focus. My decision to use a single instructional unit reflects my ethnographic commitment to make sense of ‘speech events’/activities as part of the pedagogical whole, from the teacher’s perspective (3.2, 5.1). I selected this particular instructional unit because student participation is pronounced, but not untypical of lessons in the data set overall (*Table 3*).

The chapter is structured into four sections, each of which corresponds to a distinct activity in this instructional unit (5.8.2). In each section, I present analysis alongside transcript extracts and, where relevant, interview and/or focus group data. I discuss the features of the activity, and highlight the relation to my claims. I distinguish between lesson transcript extracts, and my interpretation of the data by indenting the transcript extracts. I use line referencing to indicate the location of extracts in the instructional unit, and the full transcript is presented in Appendix F. I distinguish between description of non-verbal behaviour and verbal utterances by further indenting verbal turns. Transcript conventions are discussed in section 5.7.1, and a full list of conventions is included at the start of this thesis. In the chapter summary, I reflect upon aspects of student participation in these mathematics lessons, and specifically the three main claims outlined above, which are illustrated in the chapter.

7.1.1 Introduction to this instructional unit

In this instructional unit, the teacher’s objective is to show students how to calculate the surface area (SA) of a cuboid. The mathematical content for this unit includes the terms cuboid, surface area, face, rectangle, length, width, height and pairs; and the practices of drawing, identifying, counting, measuring and multiplying. In the teacher’s words:

> T: The objective is to know how to draw a cuboid, what a solid is, and when a solid is called a cuboid. They should know that a cuboid has six sides with sides face each and equal. We learnt also how to find to the surface, and that this surface is obtained by using the area of the rectangles obtained in the cuboid.
>
> (09.17.TIT)

It becomes clear in this lesson, that the teacher and students have distinct methods for calculating the SA of cuboids. The teacher’s method, taken from the student textbook (pages reproduced in Appendix G), is based on the understanding that a cuboid consists of three pairs of rectangles. His method, which he tells, shows and demonstrates to students in the lesson, is to calculate the SA of the three different rectangles and multiply each answer by two before adding the three numbers together. In the course of the unit, students share three different methods for calculating the SA of cuboids, individually and collectively. This is striking, given the pedagogical value attributed to enabling students to express their thinking (Lemke, 1990; Mercer, 1995; Webb & Webb, 2008) , and it is notable here that students do so multimodally. The teacher builds on the students’ contributions to represent his own method, which reflects ‘constructivist pedagogy’ (Chisholme & Leyendecker, 2008), and judging by student responses in the lesson (7.5), and post-lesson comments (09.17.SGIT, *Table 5*), are effective for some students at least.

The first and last methods are accepted by the teacher as valid, and a number of students, with the last being the most popular. This final method, which students report that they learnt in primary school (09.17.SGIT, *Table 5*) consists of calculating the ‘surface of base’ (SB) which is the surface of the two square ends of the cuboid; and then calculating the ‘lateral surface’ (LS) which is the surface area of the four sides of the cuboid. The method for obtaining the SA of the cuboid is to calculate one SB and multiply by two, to get the total SB. Then, to calculate one LS and multiply by four to get the total LS. Finally, the total SB and total LS are added together to get the SA of the cuboid. As the teacher points out at the end of this unit, both his preferred method and the method preferred by students can be used to calculate the SA of a cuboid. While the teacher sees the cuboid as consisting of three pairs of equal rectangles, the students see the cuboid as consisting of one pair of base rectangles, and a set of four lateral rectangles. These different ways of seeing the cuboid leads to interactions which demonstrate the power that students have to shape interactions and activities and communicate mathematically in these lessons; the extent to which the teacher enables them to do so; and the way in which he uses student contributions to build their understanding.

The recording indicates that all students in this lesson have a notebook and pen or pencil. Five coursebooks, including the teacher's book, are visible in this lesson.

Table 11 below provides a summary of the activities which comprise this instructional unit and the time for each activity. A full transcript of this instructional unit is provided in Appendix F.

Activity	**Time**
Preparation	2 minutes 8 seconds
Presentation	7 minutes 1 seconds
Demonstration	8 minutes 32 seconds
Questions	5 minutes 7 seconds
Summary	1 minute 38 seconds
Total time	27 minutes 11 seconds

Table 11 Surface area of cuboids, activities and times

7.2 Preparation

The way that students participate in this extract is typical of their participation in preparation across the data set (*Table 3*). The activity begins with the teacher writing on the board from the textbook, which he holds open in his left hand. Occasionally, he pauses to look at the book or check his work. He does not look at or address students until the end of the activity.

> The teacher writes text from the textbook onto the board. Some students turn to each other and talk together. Others look around the room. Some students copy what the teacher is writing. The teacher adds the label 'face' to the diagram, linking the word to the top of the cuboid diagram with a line.
>
> (Line 1)

The text he writes comprises a unit heading followed by a definition, a sub heading followed by another definition and a diagram (*Figure 12*, below).

Unit 7 solids
definition
is a dimension figure that has a flat surface for each face
2.1 Cuboid
definition a solid bounded by three pairs of identical face which are rectangle
(3D diagram of a cuboid, labelled 'face')

Figure 12 Surface area of cuboids board-work

The teacher finishes drawing the diagram of the cuboid. He steps to the left of the board and faces the class as he says quietly:

Ssss..eh…keep silent….

The majority of students turn to look at the teacher.

(Line 2)

Students participate in two distinct ways to co-construct this activity with the teacher. Firstly, many students begin to copy the text from the board into their notebooks despite the fact that the teacher does not tell them to do so. As I pointed out in Chapter 6 (6.2) this suggests that students are familiar with the activity. In addition, it indicates a level of agency as students choose when to write. Some students copy down the text and begin doing the practice exercises as soon as they are written on the board. Others wait until the exercises are being completed on the board by the student volunteer, with support from the teacher, before copying them down. Others still, wait until the text is complete before copying it into their notebooks. There are few examples of the teacher checking student notebooks in lessons. Instead, students appear to check their work against the text which is written on the board and the texts written by classmates. This approach means that students can work at their own pace and do more or less to contribute to the construction of the text on the board. *Figure 13*, below, shows some students writing in their notebooks while others talk together.

Figure 13 Student behaviour during preparation

The second way that students participate to co-construct the activity is by 'mis-behaving' in predictable and permitted ways. A degree of student side-talk is a continual feature of these lessons, but 'side-talk' is louder in preparation than in other activities, and students often turn to face each other and occasionally pass classroom materials. Because this is 'normal' behaviour in preparation, this 'mis-behaviour' serves to co-construct the activity as much as writing in their notebooks (Lemke, 1990). The opportunity is apparently afforded because the teacher has his back to the class during preparation, which suggests the extent to which the teacher controls student behaviour through gaze and his position in the room in other activities. Data from the student microphone indicate that students use the opportunity to prepare themselves for the lesson. A typical utterance is presented below:

> S1: Alice Wantije kuri iyo ruler *(Can you please lend me a ruler)* Alice wantije *(Alice please lend it to me)*
>
> (09.17.SMT)

7.3 Presentation

Next, I illustrate how students participate during 'presentation'. Overall, in this extract we see students participate multilingually and multimodally to co-construct the activity with the teacher. Student participation in this activity is closely controlled by the teacher. In general, as the teacher makes clear in this extract, they are expected to show that they 'follow' his presentation through body language (i.e., facing forward or facing the board, writing in their notebooks); gaze (i.e., looking at the teacher, the board, their notebooks); and, for some students, by responding to the teacher's tag questions to construct 'dialogue', out of what is effectively teacher monologue. These responses are most often performed by a single student, audibly and in English, apparently on behalf of the class. The rest of the students participate by 'following' the dialogue-presentation. As I proposed in chapter 6 (6.3), the purpose of presentation and the teacher's use of 'questions' in the activity, is to gain, maintain and direct student attention to key information and processes which are to be used later in the lesson. In addition, in this extract, we see how the teacher uses dialogue to manage student behaviour. This extract presented here begins one minute and 32 seconds after the beginning of the activity and lasts for two minutes and 21 seconds out of a total time of seven minutes and one second for the activity overall.

> The teacher walks to the front right of the room, holding the textbook. He picks up a piece of chalk from a desk there as he starts talking, looking towards students seated on the right.
>
> > We are going to see how to find ..
>
> His voice increases in volume as he straightens up, turns and walks towards the board
>
> > how to find the ..surface ..area of cuboid…
>
> He re-draws a line of the diagram of the cuboid, then continues:
>
> > You see? ..This is called the? .. length Sibyo? *(isn't it?)*
>
> As he says 'length' and 'width' he adds the words as labels onto the diagram.
>
> (Lines 20-4)

As we saw in chapter 6, in this first section the teacher is constructing a multimodal mathematical text (O'Halloran, 2015) naming the mathematical terms as he labels a diagram on the board. In addition, his utterances are scattered with pauses, silences which he uses to draw student attention. This impression is supported by his use of tag questions (e.g., you see?, and sibyo? (*isn't it?))* preceding the pauses in the final line (Probyn, 2009). *Figure 14*, below, illustrates student behaviour while the teacher is presenting information to them. Some students are watching the teacher and making notes, others are turned away and talking with classmates.

Figure 14 This is called length

The extent to which this activity is co-constructed with students is evident by the way in which the teacher leaves short pauses in which, most often, a single student answers, as can be seen next:

> A single student answers in the two second pause the teacher leaves:
>
> > yes
>
> The teacher continues:
>
> > This is called the? ..width. Sibyo? *(isn't it?)*
>
> Again, a single student answers in the short pause left by the teacher, in a voice that is audible to the class.
>
> > yes
>
> Other students are talking quietly, and some are turned to each other.
>
> (Lines 23-5)

The teacher's reaction at this point indicates that he perceives that some students are behaving inappropriately. He calls for quiet, through the sound 'sss!' then, repeats a request for students to 'look here' and 'follow'.

> > SSS! This is called ….
>
> The teacher writes the label 'height' and then looks up and says:
>
> > Are you looking here? ….

> Most students turn to face the front. A single student answers audibly and in English:
>
> > yes
>
> The teacher continues looking up and around the room, as he says:
>
> > are you .. looking for this figure? …
>
> In the pause left by the teacher, a single student answers audibly:
>
> > Yes … yes…
>
> The teacher walks towards the right of the room, and says in a low tone:
>
> > Follow …
>
> His gaze moves around students seated on the right as he walks. Students either look at the board or write in their notebooks. Again, a single student responds to the teacher, in the pause:
>
> > Yes …
>
> (Lines 26-31)

The teacher has used dialogue, co-constructed with a student to manage student behaviour, in a way that makes the expected behaviour for students in this activity explicit. In addition to the individual students who respond verbally to the teacher, others respond by looking at the board or writing in their books. Next, the teacher, apparently satisfied, resumes the presentation. Again, he constructs presentation as dialogue with a single student:

> The teacher walks towards a desk in the middle of the front row on the right side of the room.
>
> > For a cuboid has? ..
>
> The teacher extends his arm, and a student hands him the model cuboid. The teacher continues:
>
> > has six face…every two face are equal … and are rectangle..
>
> A student responds, quietly:
>
> > *yes*
>
> The teacher continues, still facing the students seated at the right back of the room:

Are you looking?

Again, a student responds, quietly:

yes

The teacher continues to talk, holding the model cuboid aloft as he does so.

You see you know to calculate the the surface area of triangle .. sibyo? *(Isn't it?)* … SIMUBIZI? *(Don't you know?)*

(Lines 32-7*)*

The teacher's raised his voice on the second tag question (SIMUBIZI? *(Don't you know?),* is a response to the lack of student response to his first sibyo? (*Isn't it?).* Again, this indicates that he expects at least one student to co-construct the dialogue with him, and, indeed, that the dialogue is dependent on student participation. The teacher's position in the room at this point is shown in *Figure 15*, below:

Figure 15 SIMUBIZI? (DON'T YOU KNOW?)

It is notable that the teacher appears to be addressing a group of students at this point, rather than the whole class. I suggest that he is performing the dialogue with these students as a means of managing their behaviour. Other students are expected to watch the 'dialogue', which, as I already pointed out, is a form of presentation. At this point, the delay in students replying seems to reflect the fact that the teacher has said "triangle" when he presumably meant to say “rectangle”. Notably, rather than highlighting this error, a student from the group that the teacher is addressing echoes the teacher, quietly:

Gukarikireiting *(To calculate)* the area surface

(Line 38)

The teacher responds to the student by completing the sentence. In doing so recognises and corrects his mistake:

Of a triangle. .. of of a rectangle. SIBYO? (*isn’t it?)…* Length times width

A single student from the group that the teacher is addressing responds, quite loudly.

eeeh, yes

(Lines 39-40)

This short exchange shows how students collaborate with the teacher to co-construct the activity. This is evident in the interaction which follows, in which the teacher appears to bid for confirmation that students are “following” and students respond:

The teacher continues holding the model aloft and turns to face the middle of the room, as he repeats the tag question:

Sibyo *(isn’t it?)*

This time several students answer audibly in the pause left by the teacher:

Yes. Yes. Yes.

The teacher rephrases his tag question:

Sikobigenda? *(Isn’t it?)*

Again, several students answer, audibly.

Yego *(yes)*

(Lines 40-4)

The focus of this exchange seems to be classroom management. The teacher asks students to show they follow, and students respond, emphasising their response in two ways. Firstly, through the number of students who respond and the volume of their response which stands out in contrast to the ‘standard’ of one student answering; and secondly, by the ‘switch’ to

Kinyarwanda, apparently used to gain and maintain student attention (Probyn, 2009) . After this interlude, the teacher resumes the presentation.

> The teacher turns back to face the students seated on the right as he continues:
>
> > Ubwo ubuso dufite face zingahe? .. (*The surface has how many faces?)*
>
> After a two second pause he answers his own question.
>
> > Esh/eshstu/ *(six)*
>
> As he begins to talk, several students chime in with the answer, overlapping with the teacher:
>
> > /Six/ Hatsheput *(Six)..*
>
> (Lines 45-6)

At this point, it seems that the teacher is checking students' knowledge, and several are keen to show that they know the answer, which they do verbally.

> The teacher continues talking, still facing a small group of students but in a voice that is audible to the class. He touches the different faces of the model cuboid as he talks:
>
> > Kubera dufite two face zigiye zingana ebyiri ebyiri. Turashaka ubuso bwa face eshatu zitandukanye. Sibyo? Noneho kuri buri face tugende dukuba kabiri. *(Because every two sides are equal pairs. We find the surface area of the three different sides. Isn't it? Then we multiply the total by two)*
>
> A single student repeats the teacher's last word, in Kinyarwanda, in a voice that is audible to the class.
>
> > Kabiri *(Two times)..*
>
> The teacher responds with a final:
>
> > Sibyo? *(isn't it)*
>
> He hands the cuboid back to seated students. Then he turns and moves back to the board and begins to write text from the coursebook onto the board. Some students pass around the model cuboid. Many students turn to the board and begin to copy what the teacher is writing into their notebooks.
>
> (Lines 46-9)

In the final section, the teacher presents his method for calculating the surface area of a cuboid to students multilingually and multimodally. His aim appears to be building student understanding of the process. This is evident in the 'meshed' use of Kinyarwanda with English mathematical terms, which I suggest makes mathematical meaning and mathematical forms (in English) accessible to these students, combined with his use of a model cuboid and gesture. Students participate by watching the teacher, and a single student echoes the teacher's last word as if signalling that they have heard him. The teacher concludes the presentation with an emphatic 'sibyo? (*isn't it?)* before returning to the board to prepare a text for the next activity, which is 'demonstration'.

7.4 Demonstration

In Chapter 6 (6.3), we saw how the teacher co-constructed demonstration with students by positioning a volunteer as the mathematical lead and providing mathematical support to the student in a way that was accessible to the class. In this section, I illustrate how students participate in 'demonstration' using two extracts from the activity in this unit of instruction. The first extract exemplifies the power that students have to direct the teacher's behaviour in demonstration. We see how students, through non-response to the teacher's repeated invitations to volunteer, direct the teacher to present additional information and then to demonstrate an example to the class himself. In the second extract we see a student using the opportunity of working at the board to present his method to the teacher. We see how the teacher watches the student work and attempts to understand 'how he is doing it'. This indicates that students have opportunity (co-constructed with the teacher) to communicate their mathematical thinking in this activity. In both extracts, it is notable that student communication is primarily non-verbal and, as in other activities, would likely be missed by a purely verbal analysis of events.

The first extract, which lasts five minutes and 20 seconds, follows a second preparation activity, when the teacher writes a word problem on the board (see *Figure 16*, below).

Example the net of a cuboid consists of a series of rectangles. How many rectangles are there? What is the surface area of the cuboid if it measure 6 cm by 3 cm by 2 cm? Solution

Figure 16 Board-work at the start of demonstration

> The teacher completes the text by underlining the word ‘solution’ in a single stroke, then walks to a desk front left. He puts down the textbook and picks up the set square and holds it aloft.
>
> > Who can come to correct this question? Anyone who can come to correct the answer …Hari uwaza ngo agerageze? *(Who can try*) ….. heh? ….
>
> He points to the example on the board as he says ‘this question’, then turns to look and gesture out at the class. He moves to the left of the room, and moves his gaze over the students seated there. Students continue writing, chatting quietly or looking across the room.
>
> (Line 67)

As we saw in Chapter 6, the teacher cues the beginning of demonstration using a combination of multimodal resources (6.4). He moves from the middle to the side of the board, proffers the ‘ruler’ (a set square here, a protractor in the previous lesson) baton-like to potential volunteers. He looks out at the class, invites students using a ‘switch’ from English to Kinyarwanda for emphasis (Probyn, 2009), and leaves time for volunteers to respond. However, students do not volunteer. Instead, they continue writing, chatting quietly or looking across the room. The moment when the teacher asks ‘who can try?’ is captured in *Figure 17*, below:

Figure 17 Hari uwaza ngo agerageze? (Who can try?)

Thus, as in Chapter 6 (6.4), students are participating through non-response, which here, as there, is a signal to the teacher to provide additional information. This interpretation is confirmed when, as in chapter six, the teacher responds to students by providing additional support. He says:

> Let me try to calculate to draw the figure
>
> …….
>
> (140 seconds)

> Then he carefully draws and labels a diagram cuboid over a period of 140 seconds. In this time, some students copy what the teacher draws and others turn to each other and talk together. The students with the model cuboid pass it between them.
>
> (Line 68)

After the teacher has finished labelling the cuboid diagram, he makes a second bid for a volunteer using a range of semiotic resources.

> He steps back to the left side of the classroom, talking as he moves away from the diagram. He looks at the diagram, then out at the class. His first Kinyarwanda utterance is fast. The second English utterance is more deliberate. He faces the students as he talks:
>
>> Ntawaza ngo agerageze? (*Who can come and try*) .. who can come to find the surface area? … can you try?
>
> One student raises his hand and clicks his fingers.
>
> (Line 69)

The student is using a familiar signal to volunteer, but the teacher does not accept his bid. This might be because this student often volunteers in lessons and the teacher wants to give someone else a chance to 'try'. Or, teacher might be focussing on the majority of students who, by not responding, appear to signal that they are not ready to approach the task.

> He continues to look around the room. In the three second pause that he leaves, the student who has his hand up calls out:
>
>> eh teacher!
>
> (Line 70)

Again, the teacher doesn't accept. He appears to be keeping the invitation open by moving his gaze around the room, and saying:

>> Sibyo? …(*Isn't it?)*
>
> The student with his hand up calls again for the teacher's attention:
>
>> teacher! teacher!
>
> (Lines 71-2)

The teacher still does not select the student with his hand up. He seems to react instead to the majority non-response of the class because he proceeds to offer further guidance. In the interaction that follows the teacher uses dialogue to engage students in following his method.

> The teacher points to the diagram of the cuboid in the middle of the board. He speaks loudly. Most students are facing the teacher at this point.
>
> > How many rectangles are there?
>
> (Line 73)

Unlike presentation (7.3), the teacher doesn’t answer his own question. Instead, he leaves a pause of six seconds in which several students call out answers:

> > Four. Four. Two. Four. Six. /Six/
>
> (Line 74)

He ends their turn, apparently at the point he hears the answer he is looking for, by echoing the last response and extending it into a fuller answer:

> > /Six/ rectangle. Sibyo? *(Isn’t it?)*
>
> A single student calls out:
>
> > four
>
> (Lines 75-6)

The teacher constructed a space for students to participate in the dialogue, and several students used the opportunity. The teacher perceives they don’t understand, and reacts by presenting his method again.

> The teacher turns to the second diagram of the cuboid, that he has drawn in the middle of the blackboard. He counts off the sides with his chalk as he talks. Most students are watching
>
> > Iyi niyi, niyi niyi, niyi niyi yo hasi. Is six. Sibyo? *(This side and that, this side and that, and this side and the one below. Isn’t it?)*
>
> The teacher looks up and pauses for three seconds. A single student calls out loudly:
>
> > YES

The teacher says:

Sibyo? *(Isn't it?)*

The same student responds:

yes

(Lines 77-80)

The teacher is providing opportunity for students to signal to him that they understand, and that he observes and responds to students in these spaces. Apparently concluding that students require additional information, the teacher presents his method for calculating surface area again. This time he uses mathematical formula, along with the diagram, talk and gesture. He is not just repeating but *re-presenting* his explanation, shifting between mathematical modes (Barrett, 2007; O'Halloran, 2015).

He writes: S.A. (R.1), saying as he does so:

Sibyo? Urabanza ushake surface area of rectangle one. Sibyo? SIBYO? (*Isn't it? You start by finding .. Isn't it?. ISN'T IT?)*

Then he writes: S.A (R.2), as he continues:

Rectangle one and surface area of rectangle two. …Siko bimeze? Surface area of rectangle three. Noneho ugende ukuba kabiri ukuba kabiri (*Then you multiply by two)* Sibyo? …Siko bimeze?... (Isn't it?)

A single student answers, audibly and in English:

yes

The teacher finishes writing the formula, adding: S.A. (R.3).

(Lines 81-2)

Then, he makes a third bid for a volunteer.

He turns away from the board and looks out towards the class, saying:

Come …..

In the five second pause that follows, he turns a full circle, in the middle of the room, looking for a volunteer. No students volunteer. Several call out, although nothing is distinct.

(Lines 83-4)

Figure 18, below captures the teaching asking for a volunteer, and the lack of positive response from students.

Figure 18 The teacher asks again for a volunteer

The teacher turns back to the board and saying:

Ntabwo muri kubibona? *(You don't it?)*

Some students call out, but what they say is unclear.

(Lines 85-6)

For a third time, the teacher responds to students by providing additional task support. This time he uses dialogue, the diagram, and his formula to engage students in doing the calculation with him.

The teacher returns to stand in front of his diagram on the board. He faces the class, and indicates the diagram he has drawn with his left arm.

Rectangle ya mbere ngizi, zirimo ari face ebyiri. Sibyo? *(The first rectangle is here. There are two faces)*

The teacher points towards the length measurement label on the diagram as he says:

this is length .. sibyo? (*Isn't it?)*

Then he adds the labels '(l), (w), (h)' to the diagram as he says:

Length, width, height sibyo? *(Isn't it?)…..*

A single student answers to show the teacher that the class 'follow':

> yes

The teacher continues talking as he writes '2 (LxW)='

> Wenda reka dukube kabiri. Sibyo? (*Let's us multiply by two. Isn't it?)* Length and width, sibyo? (*Isn't it?)*

Again, a single student answers:

> yes

The teacher looks up at the class, and asks:

> Ni kangahe? (*How much?)*

The teacher leaves a six second pause in which several students respond, although what they say is unclear. The teacher writes: '2 (6cm x 3cm)', then asks:

> Dukubye? *(We multiply by?)*

He leaves a two-second pause in which several students answer:

> Kabiri (*Two times)* Ni cumi nagatatu, cumi na (*It is fifteen.)*

The teacher responds:

> Sibyo? …Turagira kangahe? *(Isn't it? What do we get?)*

A few students reply, their answer is unclear. The teacher writes '18' on the board, then continues:

> dukubye kabiri ni kangahe? …heh? (*Eighteen multiply by two, we get)*

A few students answer in the four second pause left by the teacher:

> Itatu gatandatu *(Thirty six)*

Teacher says:

> Centimeter square

He writes:

=36 cm2

He moves to the left of the board, looks out towards the class and says:

Hagire uza akore (*Who can come and try)* ….. for rectangle two …..heeeh?

The teacher looks around the room in the 12 second pause that follows. This time, at least three students, seated on different rows, raise their hands and click their fingers.

(Lines 87-97)

In this extract we see how students participate to shape interaction, through their non-response to the teacher's three attempts to begin demonstration. It is interesting to note that the teacher responds differently each time, moving between semiotic modes (Barrett, 2007) and providing progressively more task support (Bruner, 1974). The first time that students do not volunteer, the teacher draws and labels the figure on the board. The second time, the teacher 'presents' more verbal and written task support. Students participate through co-constructing the teacher's dialogue. The third time, the teacher uses dialogue to do the calculation with students, and several students participate enthusiastically. After this, when the teacher initiates demonstration again several students raise their hands and call out to volunteer. This is an indication that the support which the teacher has provided, in response to and using student participation has enabled some students at least to understand. Overall, the extract illustrates opportunity for student participation, which the teacher constructs in response to cues from students, and how the teacher observes and responds to students in this activity. Further, the extract provides further examples of 'meshing', where the teacher uses mathematical terms in English, as part of Kinyarwanda utterances and in combination with other mathematical modes (O'Halloran, 2015)to enable students to access mathematics and English (Setati et al., 2008).

Next, I jump ahead to the final 1 minute and 27 seconds of demonstration. The extract begins as the teacher invites a second volunteer to complete the calculation for the third rectangle pair of the cuboid:

For rectangle ya gatatu *(For the third triangle) ……………*

In the 15 second pause that follows, a number of students raise their hands, click their fingers and call out.

Eh! Teacher! Teacher! Eh! Teacher!

The teacher points towards one of the students.

(Lines 115-6)

This is captured in *Figure 19*, below:

Figure 19 Students volunteer

> The student comes to the front and takes the chalk from the teacher. The teacher hands it to him, saying:
>
> > Height times width …..
>
> The volunteer crouches to complete the calculation at the bottom of the middle-section of the board. The teacher walks over to students at the right side. He looks at the students seated there as he says, loudly:
>
> > FOLLOW! Are you follow? …what happen? Ufite ikibazo ubaze. Sibyo? …Abaze turamusobanurira ariko ntasakurize abandi bana. *(Any question? Isn't it? If you have a question please ask but don't make noise)*
>
> He turns back to see what the student at the board is doing. He addresses the student at the board, then stands watching the student work for 15 seconds:
>
> > *Yes.. Buretse, ba buretse (Wait, wait a moment) …………… (15 seconds)*
>
> (Lines 117-9)

It seems that the request to wait is addressed at the seated students, who the teacher had just invited to ask a question. Instead, the teacher watches the student who is working on the board. He appears to be trying to understand the student's method.

When the student has finished writing, the teacher asks him:

Ibyose kandi ukoze ubikuye he? *(Where do you get what you are doing?) …..*

The student at the board turns to the teacher. He replies and gestures towards his work as he talks, although his words are unclear.

(Lines 120-1)

This moment is recorded in *Figure 20*, below:

Figure 20 Ibyose kandi ukoze ubikuye he? (Where do you get what you are doing?)

Other students call out as the teacher addresses the student at the board:

Ubanza ugakora ibiri muri blaket mo imbere. Ntubize amategeko yo gukora fraction? 2 dukubye 12 nako 6. Gatata cm square? *(You start with what is in the bracket. Have you not learnt the law of fractions? Two times 12 no 6. Is it 6 cm squared?)*

The student at the board rubs out his work, then writes the teacher’s formula. The teacher walks to the left of the room and watches as the student at the board finishes writing. The student finishes and looks up towards the teacher. Then he turns to look at his work on the board and moves to his seat. The teacher looks over the class and says:

Are you follow? ………… (12 seconds)

(Lines 122-3)

In this second demonstration extract we see the student volunteer writing a method on the board that differs from the teacher's method. It is striking that the teacher apparently attempts to understand what the student is doing, allowing the student to finish working and asking him to explain his method, before correcting him.

In demonstration, students participate to complete mathematical texts on the board and to observe the completion of texts by classmates. The teacher observes and responds to students, providing support to complete the task when needed. The expected behaviour of students in this activity is made explicit through the teacher's repeated requests for students to "see", "look" and "follow" (e.g., line 20, 22, 27, 28, 30, 35,37, 52,62, 118,123). Moreover, through his use of gesture, pause, tag questions, intonation and verbal language he engages students in looking at the multimodal mathematical text, and in lines 87-97, in doing the calculation with him. Nevertheless, students have agency to direct this activity, enabled by the teacher. In the first extract, we saw how students used the 'space' to volunteer to signal to the teacher, through non-response, that they required additional information. In the second extract, we see a student at the board using the opportunity of showing the teacher and the class to present an alternative method. In both cases the teacher observes and responds to students. In the final activity, 'student questions' (7.5), the teacher provides additional opportunity for students to express their mathematical thinking, verbally and multimodally. Again, we see how he observes, and attempts to make sense of, their mathematical thinking.

7.5 Questions

The final activity presented in this chapter is 'questions', an activity which the teacher frequently uses to close units of instruction, and sometimes, as here, to resolve misunderstandings by providing students with an additional opportunity to communicate with him. Typically, in this activity, the teacher invites students to ask questions and students respond by raising their hands, by saying 'no question' or not doing either of these. If students do not request to ask a question, the teacher begins the next instructional unit. If students indicate that they have a question, the teacher gives permission for them to ask, verbally and/or by gesturing to the student. Students ask their question verbally, remaining seated, and the teacher responds, verbally and referring to the text on the board. Alternatively, as in this extract, if the teacher does not understand what the student is trying to say, he may ask the student to show what they mean on the board before responding.

The teacher begins the activity, by inviting students who “don’t know how we are doing it” to put their “hands up” (Line 124). At the start of the extract, the teacher seems to perceive the need to manage student behaviour because he reminds students to raise their hands to volunteer and wait to be selected although this, like other activities is an established routine. On one hand, by asserting the ‘rules’ of the activity the teacher is seeking maintains control over the interaction. On the other, as we see here, using this familiar interaction students are able to express themselves and be heard by him and other students. The first student to ask a question, indicates her disapproval of the method which the teacher has presented. She describes her preferred method, which appears to be to calculate the SA of the six rectangles separately, then add them together. Several other students agree with her. The teacher listens, then shows these students that their method is “fine too” (Line 136). A number of other students continue to show that they don’t understand or agree with either method. In response, the teacher gives one of these students the chalk and asks him to show his method on the board. Instead of evaluating this student’s work himself, the teacher asks the seated students if they agree with the student’s method and the majority indicate that they don’t. Finally, the teacher gives the chalk to a third volunteer who, directed by other students, shows another method for calculating SA. This third and most popular method is to calculate the ‘surface of base’ and multiply it by two, and the ‘lateral surface’ and multiply it by four, and the add the two figures together. The teacher watches closely and then closes the activity by demonstrating, multilingually and multimodally, that his method and this third method are ‘the same’. The activity, presented here in full, lasts 5 minutes and 7 seconds.

> The previous student volunteer returns to his seat. The teacher stands against the left wall of the room, about half-way down. He looks towards students seated on the right side. He raises his right hand and says:
>
> > Abantu batari kubona aho turi kubikura ni hagire umanika…Hands up (*If you don’t how we are doing it, please…)*
>
> A student calls out. The teacher raises his hand again, as he says:
>
> > SSS! Kumva aho turikubivana Hands up (*How we are doing it*) ……….
>
> (Lines 124-5)

The teacher has apparently not accepted the students who called out, because he has transgressed the ‘rules’ of this activity. Instead, he repeats the invitation to ask a question, again combining the raised hand gesture with the phrase “hands up”, further emphasised by the ‘switch’ to English.

> In the 10 second pause that follows, several students call out, but what they say is unclear. The teacher gestures around the room with his arm extended. Three students raise their hands. One calls out:
>
> > Teacher! teacher! …
>
> The teacher gestures with his right arm towards a student. She says something, facing the teacher. What she says is not captured. The teacher walks toward her as she is talking. He raises his arm, as he says:
>
> > eh?
>
> (Lines 127-9)

It seems that the teacher has not heard her question, and has signalled her to repeat the question through the combined gesture and exclamation.

> The student speaks again, louder:
>
> > Ikibazo. Waretse tukabikorera icyarimwe kugirango tubone uko tubikora neza? Biriya biratujijisha tukabikorera icyarimwe nkuko formule ibitwereka Eh! Eh! (*That's a problem. Why can't do all at the same time so that we do them properly? That method confuses us and we end doing all of them as the formula shows. Eh! Eh!)*
>
> (Line 130)

This emphatic utterance suggests the student's dissatisfaction with the teacher's method ("that's a problem"). She describes her preferred approach, to "do all at the same time". This could mean that she would prefer to calculate the surface area of each of the six rectangles separately then add them together. The teacher seems to interpret her description in this way. He tries to confirm his interpretation with her, pointing towards the formula on the board and asking:

> > Eh! Ukabikorera icyarimwe? (*Are you doing it altogether?)*
>
> Several students raise their hands and call out:
>
> > iiih (*yes)* Yes eh! Teacher! Teacher!
>
> The teacher moves to the far-right of the board saying:
>
> > Buretse turebe (*Wait a moment*)..
>
> He stands to the right of the board and says:

> Ukabiteranyiriza hamwe? (*Are you adding them all together?)*

At least three students answer, loudly:

> YES YES YES

The teacher gestures towards the formula in the middle of the board as he says:

> Nabyo nta kibazo, Sibyo? Ubwo ni, ni total y izi surfaces zose tubonye, Sibyo? *(That's fine too. That's the total of all of these surface areas we got. Isn't it?) ………… (12 seconds)*

(Lines 134-7)

The teacher is apparently showing students that the student's method, to "do all at the same time" (Line 130) and the formula which is written on the board lead to the same answer. He makes the connection using gesture and verbally, 'meshing' Kinyarwanda with English indicating that his focus is on meaning. Nevertheless, he seems to feel that more explanation is needed because he begins writing on the board.

In the 12 second pause that follows, one student calls out, although only part of what he says is audible:

> Eeeh……….surface…./unclear/

Meanwhile, the teacher writes:

S.A = 36 cm2 + 24 cm2 + 12 cm2 =

Then he points to the calculation and asks:

> Turagira kangahe? (*What do we get?) ….*

Several students reply in the four-second pause he leaves, but nothing is distinct. The teacher faces the calculation he has just written and says:

> Mumbwire..dufite kangahe? (*Tell me..what do we get?)* ………..

In the 11 second pause that follows, several students call out, louder than before. Of these, two utterances are distinguishable:

> S1: Ntago ndi kubyumva! Bon nyine … (*I don't understand)*

> S2: Mirongo itandatu na gatandatu uteranyije..Mirongo irindwi na kabiri (*Sixty six plus seventy two)*

The teacher moves his chalk across the calculation he has written on the board, from left to right, then writes at the end of it:

72 cm2

He looks up to the class and says:

> Eh? …..

In the five second pause, the teacher looks at the students

(Lines 137-142)

In this section the teacher seems to be trying to communicate his method to students again, in a more concrete way this time by using the numbers from the exercise on the board. He writes the calculation without an answer, and seems to leaves time for students to work through it. He indicates the process of doing the calculation by gesturing along the calculation with his chalk, before writing the answer. Finally, he seems to check if students are satisfied by looking at the class, and exclaiming "eh?", followed by a five second pause which suggests an opportunity for students to express if they agree or do not. It seems that at least one student, seated at the back of the room, signals to the teacher that he is not satisfied, because:

The teacher nods towards a student seated on the back right of the room and says:

> Genda uyandike eh! ku kibaho turebe.. Turebe ko twayikorera ubugororangingo. *(Go and write it. Eh! On the blackboard..so that we can correct you*)

As he talks, he moves towards the student and hands him the chalk.

(Line 143)

It appears that the teacher uses this familiar gesture to establish 'demonstration', where a student presents to the class on the board (6.4, 7.4). This moment can be seen in Figure 21, below:

Figure 21 Genda uyandike (Go and write it)

In the 15 second pause which follows, the student moves to the front and begins to write his method on the board. The teacher stands to the side and faces the student. Most of the other students in the room look towards the student. The student writes:

S.A. Lx2 + Hx2 +Wx2

(Line 144)

The level of attention is high, as is evident in *Figure 22*, below, where we see all faces turned to watch the student at the board.

Figure 22 The student shows his method

As the student finishes writing, the volume of student side-talk increases. The teacher looks around the class and gestures to the student's work on the board as he says:

Eh! ni iriya mwize? (*Eh! Is that what you learnt?)*

In the six second pause that follows the teacher moves his gaze around the room. The student at the board turns to the class. Several students call out:

S1: OYA *(NO)*

S2: REKA DA *(NO WAY)*

S3: OYA *(NO)*

S4: OYA *(NO)*

(Line 145-6)

The teacher is apparently asking the seated students to evaluate the student's work, with his question to them and by leaving the pause, and several students respond emphatically. This moment is recorded in *Figure 23*, below.

Figure 23 Ni iriya mwiza? (Is that what you learnt?)

It appears that the teacher concludes that students disagree with the method which has been presented, and perceives the need to invite another student to show their method.

He points towards the students seated on the right of the room, and says:

Yandike iye, nawe urandika iyawe, Sibyo? (*Write yours and they write theirs. Isn't it?)*

One student, seated nearby, says:

> > Ngo nawe jya kwandika! *(Go and write yours!)*
>
> The teacher looks again at the formula which the student wrote on the board. He walks towards the student at the board saying:
>
> > Babu' buretse.. iyi nayo nayibonye birangana *(Wait a moment.. I can see that they are equal) …*
>
> The teacher gestures towards the student's calculation. the student faces the teacher and also gestures towards it.
>
> (Lines 147-9)

Again, the teacher seems to be trying to make a connection between the student's work and the method he wishes to teach. This moment is recorded in *Figure 24*, below:

Figure 24 Babu buretse (wait a moment)

> The teacher takes the chalk from the student, who returns to his seat, then turns to the class and says:
>
> > Birangana n ibi *(It is equal to this)*
>
> Several students call out. What they say is unclear.
>
> (Line 150)

It seems that there are many students who are still not satisfied and intend to show the teacher that they want to show their method.

The teacher points towards a student seated at the back right of the room. He says:

Hagire uza yandike iye nawe *(Who can come and write theirs? Let him try)*

The student walks over to the teacher and takes the chalk from him. The teacher smiles broadly as he hands over the chalk, saying:

Come and write your formula

(Line 151-3)

The teacher's smiles, which indicates that he is enjoying this interaction.

In the five second pause that follows, the volunteer starts writing on the board. The teacher stands to the left of the room and watches closely, as do most students in the class. In this time, a student calls out:

The surface. the surface. eceka. Ntago ari surface. Bari gushaka /surface/ (*It is not the surface they trying to find)*

(Line 153)

It seems that the student who has called out is trying to direct the student at the board. The teacher appears to think so, and asks the student to stop his utterance overlapping with the student's:

/Mumureke/ Mumureke ariko.. (*Let him try. Let him try..)*

The student at the board turns back to face board work in the middle section.

(Line154)

It seems that he is trying to recall what the teacher presented before. The teacher apparently interprets the student's movement as such, and says:

Nonese ko uri kureba ibyo twakoze? (*Why are you looking at what we did?)*

The student at the board turns to look at the teacher, exclaiming:

Ehhh

The teacher continues:

Turi kukubaza formula uzi yandike …..(*We are asking you to write your formula)*

The student points to the text on the board, facing the teacher as he says:

> Nagirengo upointed ya total surface cyangwa lateral surface? *(I want to point the total surface or lateral surface?)*

(Line 155—7)

This moment, when the student communicates with the teacher multilingually and multimodally, is depicted in *Figure 25*, below:

Figure 25 The student asks the teacher

A seated student, calls out:

> Ni lateral surface *(It is ..)*

The teacher exclaims:

> eh?

(Lines 159-60)

At this point, the teacher seems to be encouraging the student who has called out, using the exclamation 'eh?' as a cue for them to repeat their response to the student at the board. At any rate, the seated student does so, louder this time:

> S1: Ni lateral surface (It is…)

At least two other students call out. The following statement is audible:

> S2: Surface of base plus lateral surface ….

(Line 161)

In this time, the student at the board adds figures to his formula. Then he turns to the teacher and opens his arms wide. This moment, when the student appears to be presenting his method to the teacher, is recorded in *Figure 26*, below:

Figure 26 The student shows the teacher

In the next 10 seconds, the volunteer starts walking back to his seat. Some students call out to him. The following is audible:

OYA OYA lateral surface /unclear/ (*NO NO*)

The student volunteer turns and goes back to the board. He rubs out and then rewrites the last letters 'LS'. Then he walks to the teacher and hands him the chalk.

(Line 162)

This sequence is striking in the way that the students work together, using the routine of 'demonstration' to communicate their mathematical thinking to the teacher. Normally in demonstration, the teacher directs the student at the board, where needed, to show the class the target method. In this sequence, the students work together to show the teacher and this is enabled by the teacher. Thus, they are using the routine of demonstration flexibly, in the context of this activity. Next, the teacher uses the terms which the students have used in their method to explain his method to them.

As the teacher takes the chalk back from the student, he moves to stand in the middle of the room, faces the class and says:

How many surface of base?

He raises the model cuboid and touches the two square ends, saying:

> Dufite bases ebyiri.. sibyo? Sibyo? (*We have two bases.. isn't it? isn't it?)*

The teacher steps back and begins to write on the board. He writes under the calculation that the last volunteer wrote. He writes, below the 'S.B' that the volunteer wrote:

= (2LW) +

As he does so, he says:

> Sibyo?..Singizi? …..Si izingizi?(*isn't it?.. it's this? ….Is it this?)*

(Lines 163-5)

The moment where the teacher is making the connection between the two methods is shown in Figure 27, below:

Figure 27 Si izingizi? (is it this?)

Teacher steps to the side and turns to the class. He shows students the four long sides of the model cuboid as he talks.

> Noneho lateral surface ..Si ibihande, bine?... Si bine? *(Now… not four sides? not four?)*

(Line 165)

This quick switch from comparing the two formula, to showing students using the model is captured in Figure 28, below:

Figure 28 Si bine? (Not four?)

Teacher steps back to the equation, on the board as he continues:

Nese urabona hari aho bitaniye n' ibi? (Is there any difference between these sides?)

…

A student calls out:

Ahubwo Iyongiyo *(You can use that)*

The teacher exclaims:

Eh?

Another student calls out:

Niyo yaba nziza (*That one is much better)*

(Lines 167-170)

In this exchange, the students express their opinions in the space provided by the teacher. The teacher responds with another attempt to explain his method.

In the 22 seconds that follow, the teacher writes below the students' formula on the board. Meanwhile, several students call out:

S1: Ni iyo ni iyo *(That one. That one)*

S2: Iyo niyo wafata *(You can take that) /unclear/*

S3: Ahubwo Iyongiyo *(You can use that)*

S4: niyo yaba nziza *(That one is much better)*

The teacher finishes writing, circling the formula he has written (see *Figure 29*, below).

(Student method): ST=SB+LS
(Teacher method)=(2LW)=2LH+2WH

Figure 29 The students' and the teacher's formula on the board

He says:

Ahubwo iyi niyo yaba nziza (*But this is one is better)*

Then the teacher points to his equation and says:

Ibi nibyo bya….Iyi niyo lateral surface.. Sibyo? *(That is….that is the lateral surface. Isn't it?)*

As he speaks, beneath 2LH+2WH, he writes:

L.S.

He continues to talk:

Ikaba surface of base.. *(This is …)*

As he speaks, beneath 2LW, he writes:

S.B.

He says:

Si ibi se? Turi kubireba? (*Isn't it? Do you see that?)* … byo mwize ntaho bitaniye n ibi, Sibyo? …Sibyo? (*There is no difference between these and what you learnt Isn't it? Isn't it?*)

Three different students answer, in agreement now:

S1: Yes.

S2: Yes.

S3: Yes.

(Lines 171-5)

Here the teacher has used the students’ own terms (lateral surface and surface of base) to explain the method he presented before. Apparently as a result of his responsive approach, more students express agreement at the end of this extract than at the beginning. The teacher seems aware of this, as he now moves to close the activity:

> The teacher moves to the middle of the room. He faces the class and holds the cuboid aloft as he says:
>
> > Formule ntago yakubera imbogamizi, ahubwo ikibazo ni uko wabona igisubizo….Sibyo?... (*The problem is not the formula but how to find the answer. Isn’t it?)*
>
> In the three-second pause, two students answer audibly:
>
> > S1: Yes
> >
> > S2: /Yes/
>
> The teacher continues:
>
> > /Form/ula uzi yose uzajye uyikoresha, sibyo? Ah, ikibazo…Igisubizo gihure ..sibyo?(*You can use any formula you know. A problem, the same answer. Isn’t it?) .....*
>
> The teacher walks back to the board. In the five seconds before he talks again, several students are talking. At least two can be heard.
>
> > S1: N’igisubizo gihure *(It is the same answer.)*
> >
> > S2: Icya mbere cyaducanze *(The first one is confusing)*
>
> The teacher moves back to the board and points to the formula that he wrote. He says:
>
> > Ariko… iyi formula iri very simplified..Niyo mpamv…Niyo naba conseilla gukoresha.. Sibyo? Urabona iyi itari simplified? Ni uko ari ubwa mbere muyibonye *(But …This formula is very simplified. That’s why. I advise you to use it. Isn’t it? Don’t you see that this formula is easier?)*
>
> A student cuts in loudly, pointing to the part he is referring to:
>
> > Iyongiyo ya des…(that one)

The moment is captured in *Figure 30*

Figure 30 Iyongiyo ya des (That one)

> Over the next 6 seconds, several other students call out loudly. The teacher moves to the left of the room, he picks up the coursebook and looks inside it.
>
> (Lines 176-181)

After 10 seconds he moves towards the board and begins ‘summary’, to end the instructional unit. This final activity takes 1 minute and 38 seconds.

In this activity we see how the teacher and students negotiate student participation within the activity framework of ‘questions’, including a ‘demonstration’ sequence in which the student at the board is guided by classmates and not the teacher. We see students express three different methods for calculating the surface area of cuboids. The first, which several students endorse, is to calculate each rectangle separately, then add the six figures together. As the teacher points out, this is a different method to reach the same answer. The second student-presented method, which other students vehemently disagree with, is to multiply length, width and height of the cuboid by two. The third method, SB x2, plus LS x 4, seems to have the most support from students. The teacher provides opportunity for students to work together to express their method. In addition, it is striking how he ‘bridges’ between the students’ and his method, for example by writing and saying the terms the students use in comparison with his own method. This approach seems to be effective in helping some students at least to understand, as evidenced by the number of students who verbally agree with the teacher. In addition, this conclusion is supported by student comments in the post-lesson interview:

S2: (…) the first formula was confusing but after receiving explanation I understand now there is no problem.

I: What did you enjoy most in the lesson?

S2: The part I enjoyed the most is when we studied the formula we saw in P6 (primary school grade 6) because I now understand it very well. We recalled what we saw in P6 with much more understanding.

(09.17.SGIT)

The teacher’s post-lesson comments (below) indicate that he saw student participation in the lesson as positive.

I: What were the most interesting parts of the lesson?

T: The activities given to students. They tried to participate actively. They also tried to ask questions by comparing what we did and what they have seen in primary, if they match, and they tried to correct mistakes inherited in primary.

(09.17.TIT)

It is telling that, while students indicate that they ‘follow’ the teacher during presentation, their participation in subsequent activities indicate that a number, and perhaps the majority of students did not understand at this point. This conclusion is confirmed by a student’s comments after the lesson:

I: Who can tell us what you learnt today? Yes?

S1: we learnt geometry.

I: you learnt geometry? Which part of the lesson interested you the most?

S1: At the beginning we did not understand anything but along the way we started to understand.

(09.17.SGIT)

7.6 Chapter summary

In this chapter I illustrated the findings of this study in response to the second main research question. I find that students participate in lessons, multilingually and multimodally; in ways which are more and less controlled by the teacher; to co-construct and at times lead interactions and activities and to communicate mathematical meanings. As is apparent from these extracts, student participation varies in different activities, and this underlines the importance of observing 'whole' instructional units and not basing judgements on the observation of parts. In preparation, the teacher does not interact directly with students, who co-construct the activity with the teacher by behaving (and mis-behaving) in expected ways (Lemke, 1990). The limited control of student behaviour by the teacher mean that students can 'self-differentiate' challenge in this lesson, and this may indicate a pragmatic response by the teacher to the different abilities of students in this class (Williams, 2019). Student participation in presentation is closely controlled by the teacher, who uses the activity to show the class the mathematical objectives and texts of the lesson. The majority of students participate non-verbally, showing the teacher that they follow by looking at the board and/or at their notebooks. Some students respond to the teachers tag questions, often with single words. Opportunities for student participation increase in demonstration, when students direct the teacher's behaviour, initially in response to the teacher's invitations to volunteer to show the class. Further, once a student has volunteered the teacher stands to the side and responds to that student, providing guidance where needed. The rest of the class are expected to participate by watching the action, and at times offering guidance to the student at the board directed by the teacher. In the second demonstration extract, we see the teacher attempt to make sense of, and respond to the students' work on the board. In 'questions' the teacher controls how students participate, ensuring that they raise their hands to ask a question. In this extract, students communicate verbally, and by showing their methods to the teacher on the board. In these lessons, students participate in mathematical practices and express their mathematical thinking multimodally and multilingually. Student participation is predominantly non-verbal, as they 'follow' the central action of the lesson, and/or show their thinking to the class. Student verbal participation is extremely limited, which reflects findings from other studies (Erling et al., 2017) and indicates the importance of investigating non-verbal and verbal participation. With the exception of preparation, student participation is closely controlled by the teacher in ways which enable students to access and express mathematical forms, meanings and practices.

8 How are the CBC and EMI constructed in these mathematics lessons?

8.1 Introduction

In this third and final analysis chapter, I present findings in relation to the third main research question: How are the Competence-based curriculum (CBC) and English Medium Instruction (EMI) constructed in these mathematics lessons?

My inclusion of this question reflects the understanding that, given the complex appeal of language in education and curriculum policies in Rwanda (2.3.1, 2.3.2), they are likely to remain for the foreseeable future (Milligan & Tikly, 2016). Therefore, detailed understanding of how teachers construct these policies as part of classroom practice is needed in order to inform teacher CPD that enables teachers to develop their classroom practice in ways that foster student learning and participation. Indeed, the impetus for this study came from my work as a consultant, when I found that national-scale teacher CPD was focused on improving teachers' English proficiency and learner-centred pedagogy (REB, 2017)(1.4). I found this problematic, given questions around the feasibility (and desirability) of 'English-only' instruction in Rwanda, and simplistic and generalised interpretations of learner -centred pedagogy, in this context (van de Kuilen et al., 2020). I approach this question tentatively, given the tendency of researchers to apply normative pedagogical and linguistic models in investigations of policy in practice (Schweisfurth et al., 2020, p. 9; Setati et al., 2002; Webb & Webb, 2008). To mitigate this, the question of policy is positioned *after* exploring how the teacher constructs and learners participate in lessons. The teacher and students were informed that the study was investigating the teaching and learning of mathematics and not evaluating the implementation of the CBC or EMI, and lesson data was gathered over a period of several months in an attempt to move beyond the 'model lesson' (Probyn, 2009). The teacher and students' descriptions of these policies in interviews and focus groups were used as a basis for identifying their construction of policy in lessons, in addition to my own observations (5.7).

In this chapter, I present findings and analysis with regards to each policy in turn. I begin with the CBC. I structure the section using two claims made by the teacher about his lessons. These are, in 8.2.1, that students are active; and in 8.2.2, that students help each other in these lessons. I illustrate these claims with reference to the lesson data presented in Chapters 6 and 7. I close the section by demonstrating the central role of the teacher in enabling student participation in these lessons and highlight my concern that neither he nor other teachers at this school refer to their roles in lessons. Next, I turn to EMI. I begin by reflecting on how the teacher and students talk about EMI, which, I argue, is significant in evaluating the construction of EMI in these lessons and the impact of the policy overall. I go on to make two main claims about the construction of EMI in these lessons, which I illustrate with extracts from the instructional units presented in Chapters 6 and 7. These claims are, in section 8.3.1, that EMI is constructed as the language of mathematics; and in 8.3.2, that EMI is constructed as a 'visible' language. Next, I turn to two key factors which explain the ways in which EMI is constructed in lessons. Firstly, in 8.3.3, the teacher's positioning of himself as a mathematics and not a language teacher; secondly, in 8.3.4, his stated belief that language is not that important for mathematics. In 8.3.5, I review the teacher's stated language policy, which is to teach in English and explain in Kinyarwanda. In the conclusion to this chapter, I reflect upon methodological issues around separating language from mathematics, and language policy from pedagogy.

8.2 The competence-based curriculum

Perhaps not surprisingly, given the 'unitary' political climate in Rwanda (Samuelson, 2012; Samuelson et al., 2010), this teacher is unreservedly positive about the CBC in our initial conversations, which reflects the findings of other researchers (van de Kuilen et al., 2020). He says he enjoyed the district level training, and uses the CBC coursebook in his lessons. He was quick to show me his folder of CBC lesson plans and schemes of work (Fieldwork notes, 03.09.18). The teacher's comments about the CBC in early conversations resonated with comments made by other teachers at this school, and teachers at other schools (in my work as a consultant). For instance, he stated that:

> (In CBC lessons) The students are more active. The students do 80% of the lesson and the teacher 20% (Fieldwork notes, 04.09.18).

A similar phrase is repeated to me by two other teachers at this school in different and separate conversations (Fieldnotes, 05.09.18). In addition, the teacher said the new curriculum is "better" because before they were just teaching knowledge (Fieldwork notes, 03.09.18). This way of talking about the change, as a sudden 'switch' from the old to the new curriculum, echoes the discourse about "transformation" in the curriculum framework document (MINEDUC, 2013; REB, 2015). The similarities between these comments indicate that the teachers were repeating 'official' messages, possibly encountered during CBC training or in the national media.

However, in later interviews the teacher talked about the CBC in a more nuanced way, at least in relation to mathematics. For instance, in the extended interview, he commented that the CBC is not *always* appropriate for mathematics:

> The CBC also has some challenges for mathematics. The approach works well for languages and humanities but not for science subjects and mathematics (06.09.TIN)

He went on to explain that this is because “knowledge is more important for mathematics” (06.09.TIN). Later on, in the same interview, he said that “groupwork does not work well in mathematics lessons” (06.09.TIN). In addition, in the extended interview the teacher said that the learner centred approach of the new curriculum is not new for him but was part of his bachelor of mathematics education, at university (Fieldnotes, 06.09). These qualifications of his earlier comments indicate the ways in which the teacher has “recontextualised” the CBC (Bernstein, 1996) and some of the “implementational resources” he has drawn on to do so (N. Hornberger & Johnson, 2007), for example, from his professional education and his experience of teaching and learning his subject.

As I began to transcribe and analyse lesson data it became clear to me that the teacher was constructing lessons purposefully and to some extent effectively, but quite differently from the lessons presented in the textbook (6.2, 6.6). Nevertheless, in two separate conversations, the teacher referred to his lessons as “CBC lessons” (Fieldnotes, 04.09, 06.09), and went on to define them as CBC lessons based on two criteria: 1) Students are active in lessons; and 2) students learn by helping each other (Fieldnotes, 04.09; 06.09). I asked the teacher to describe what happens in a typical lesson, he says he begins by showing students the task, then students prepare individually or in groups and then show their work to each other and help each other to learn. He said that he finds this effective because students learn better from other students than from teachers (Fieldnotes, 04.09) which is an idea which he repeated in a later conversation (Fieldnotes, 06.09).

When I heard the teacher’s comments initially, I concluded that he was repeating what he thought he should say. I had heard similar formulations from other teachers and could see little connection between his description and the lessons I had observed. However, after I analysed the lesson recordings, in combination with teacher and students’ comments about these lessons, I saw that this was not the case. The teacher’s statements that “students are active” and “help each other to understand” in these lessons do in fact describe, at least in part, what happens in these lessons. In section 8.2.1 and 8.2.2 below, I illustrate each of these points with reference to extracts already seen in 6 and 7.

8.2.1 Students are active

From lesson data it is clear that the teacher makes continued efforts to engage students in lessons. For example, in 7. (7.2) I noted that in preparation students have a degree of flexibility about how they use the time to prepare. Broadly, given the behaviour of students in this activity across the data set, I conclude that the teacher and students' expectation is that during preparation students copy text from the board into their notebooks and get themselves ready for the lesson. This 'preparation' is necessary, due to the limited number of textbooks in these lessons and the 'English only' language of the coursebook 6.2, (Appendix E and G), (Early & Norton, 2014; Milligan et al., 2016). As I noted in section 7.2, the fact that this activity is not closely controlled by the teacher means that students can work ahead, or wait until the final text is finished on the board. In presentation, students are expected to 'follow' the teacher, as he shows them the mathematical text and task for the instructional unit to follow. The teacher's expectation that students' 'follow' is evident in his use of gesture, pause, tag questions, intonation, 'English' and at times dialogue. Take for example, the following extract from 7. (7.3):

> The teacher walks to the front right of the room, holding the coursebook. He picks up a piece of chalk from a desk there as he starts talking, looking towards students seated on the right.
>
> > We are going to see how to find ..
>
> His voice increases in volume as he straightens up, turns and walks towards the board
>
> > how to find the ..surface ..area of cuboid…
>
> He re-draws a line of the diagram of the cuboid, then continues:
>
> > you see? ..This is called the? .. length Sibyo? *(isn't it?)*
>
> As he says 'length' and 'width' he adds the words as labels onto the diagram. A single student answers in the two second pause the teacher leaves:
>
> > yes
>
> The teacher continues:
>
> > This is called the ..width. Sibyo? *(isn't it?)*
>
> Again, a single student answers in the short pause left by the teacher, in a voice that is audible to the class.

yes

Other students are talking quietly, and some are turned to each other.

(Lines 20-5)

In this extract the teacher acts to engage students in reading the text on the board. He does this by using the pronoun ‘we’ (‘we are going to see’), using ‘English’ (which, as I discuss in 8.3.2, below, is a ‘visible’ language); using pause combined with movement and gesture; using the text on the board. The tag questions: ‘You see?’ and ‘sibyo? (*isn’t it?)*, which are accompanied by the teacher looking at students, indicate that the teacher is expecting students to follow the action, and uses language (including CS) to gain, maintain and direct their attention (Probyn, 2009). Often only one or two students who respond verbally, and the teacher rarely indicates he expects more students to do so. The behaviour which the teacher appears to expect from students, and which he requires students to ‘show’ him is to look at the board, to keep quiet and copy text into their notebooks.

In ‘demonstration’, student activity is more apparent, certainly for the volunteer who works at the board. Students have more opportunities to be active than in ‘presentation’ or ‘summary’ as is evident in the extracts presented in chapter 6 (6.4) and chapter 7 (7.4). For example, at the beginning of the activity, the teacher invites students to volunteer to “come” to the front (6.4, line 17 and 7.4, line 67), and to “try” the task (6.4, line 19, 7.4). 7.4 line 69). As I noted in 7 (7.4), this gives students a degree of agency to volunteer or not volunteer. In the ‘demonstration’ extracts presented in Chapters 6 and 7, students use this agency to prompt the teacher to provide additional information to them. The student working at the board is active in doing the task and asking for support as is evident in the photos *Figure 8* and *Figure 10* in section 6.4. Seated students are expected to ‘follow’ the work of the student at the board as is evident in section 7.4, when the teacher apparently perceives they are not doing so (line 118, and line 123). Moreover, seated students are expected to ‘follow’ the support that the teacher provides to the student at the board. This is apparent through the volume of the teacher’s voice, which is in the majority of cases loud enough to be easily audible through the video camera recording. This is evident in contrast to the low volume used by the teacher when he addresses the student at the board only (e.g., 6.4., line 26 and 54).

In ‘summary’, like ‘presentation’, students are expected to ‘follow’ the teacher’s presentation closely, and this is evident through direct appeals for attention, through pause, intonation and gesture and the way that he ‘meshes’ English and Kinyarwanda. For example, in the extract presented in chapter 6.5:

The activity begins with the teacher gaining the attention of the class, as he completes the final two bars on the histogram. His back is to the class, and as he works he calls for student attention:

> look here ……….

Most students look towards the teacher. The student volunteer, on his way back to his seat, turns to look at the teacher over his shoulder. After eight seconds, the teacher turns and looks towards the seated students. He steps towards the graph, with his right hand (holding the chalk) raised to shoulder level, as he says:

> Urabona izi rectangle.. (Do you see these rectangles?)

When he says the word rectangle, he glances up to the class. Then, he turns back to the face board and says:

> Are you looking for this?

The teacher marks a point in the middle of the top line of 8th and 7th rectangles on the bar chart. His back is to the class, as he says:

> Doo! murareba? *(Are you looking?)*

He continues making points with the chalk on the top-middle line of each bar, from left to right, as he continues:

> Hano ni midpoint of this rectangle. Sibyo? ..Muri kubireba? *(Here it is in the …….isn't it? Do you see that?)*

As he says 'midpoint' he looks up towards the class. Otherwise, he faces the board as he continues to mark dots. One student answers the teacher, quietly:

> Yes ….

Over the next four seconds, the teacher continues marking dots on the chart, after three seconds he glances down at the coursebook he is holding in his left hand, his chalk still poised on the chart. Then he turns back to the board and continues marking midpoints of the rectangles as he says:

> Nitujoininga .. ..*(If we join)*

He steps to the side, so he is half-facing the class and continues:

> izi point tugakora line *(these point with a line)*

He briefly looks up as he says ‘point’, and then turns back to the board as he completes his utterance. He glances down at his book, at the same time saying:

> Sibyo? .. *(Isn’t it?)*

He turns back to the board, and continues marking points, his right arm extended to head height as he says:

> Muri kubireba? *(Do you see that?)*

A single student answers:

> Yes ..

Then the teacher draws a line from the ‘midpoint’ of the third rectangle down to the second, then continues to talk and draw a line between the other midpoints:

> Iyi line ijoininga midipointi … of this barchart. *(This joins the midpoints)* Niyo twita … *(We call it …)* frequency polygon .. do you understand..?

A few students answer.

> yes..yes…

(Lines 65-74)

Finally, in ‘questions’ students are expected to show the teacher if they would like further explanation or not. Like ‘demonstration’, students have some agency to decide whether to ask a question or not. At the same time, as the interaction at the start of 7.5 indicates (Lines 124-5), students are expected to follow the rule of raising their hands and waiting to be asked before asking their question. The students who ask a question are expected to make themselves understood, either by repeating the question verbally (7.5, Line 179) or, more often, by showing their thinking on the board (7.5, Lines 143, 148 and 152). Other students are expected to follow and “correct” the student where needed (7.5, Line 143).

To summarise this section, the data indicates that students are expected by the teacher to be active in these lessons; the teacher makes repeated efforts to engage them, using multilingual and multimodal semiotic resources flexibly; and students show the teacher that they are being active. Thus, the teacher’s claim that his lessons are CBC lessons because students are active appears to be justified.

8.2.2 Students help each other

The second claim that the teacher makes in order to present his lessons as CBC lessons, is that, in these lessons, “students help each other” (Fieldnotes 04.09 and 06.09). He provides a pedagogical justification for this approach, stating that students learn better from other students than from the teacher (ibid.). I find there is resonance between this teacher’s claim about his lessons and lesson data. As I noted in 6 and 7 (6.4 and 7.4), ‘demonstration’ is the ‘pedagogical core’ of these lessons, and is a practice reported in other studies (Barrett, 2007; Early & Norton, 2014; Westbrook & Croft, 2015). In ‘demonstration’ a volunteer student shows classmates an example on the board, thus providing a model of the process of doing the exercise and exemplifying the target mathematical concept of the lesson.

There are other examples of how the teacher engages students to ‘help’ each other. For example, when a student volunteer is having difficulty that the teacher asks seated students to provide guidance, as happens in 6.4:

> The teacher walks over to the left of the board. As he passes behind the student volunteer he says, aloud:
>
> > Karindwi afite mo kangahe? *(Seven occurs how many times?)*
>
> The teacher points to the table of information as he passes it, then stands half facing the student and half facing the class. As he touches the table he says:
>
> > Ariko ko mutamubwira ibyo yandika *(Please tell him what to write.)*
>
> Several students call out the answer to the teacher’s question (seven has?), immediately after the teacher has finished speaking and intermittently in the ten second pause that follows.
>
> > Kane *(four)* Four Kane (four) Kane (four) Four Kane (four)
>
> The teacher stands to the left of the board. For the first five seconds he faces the student, then he turns to face the back of the room and repeats the question:
>
> > Karindwi has? *(seven has?)*
>
> Again, several students answer almost immediately. :
>
> > Four. Four. Four …………….
>
> The student working at the board continues drawing neat and careful lines.

(Lines 57-60)

The strategy of engaging seated students in providing corrections to the student at the board is described in Westbrook and Croft (Westbrook & Croft, 2015, p. 43).

A further example of students helping each other (enabled by this teacher) is provided in ‘questions’ (7.5). In the extract below a seated student has called out to correct the student working at the board. The teacher signals to the student to repeat the correction, louder. Several students join in, and the student at the board uses their prompts to complete his turn.

A seated student, calls out:

Ni lateral surface *(It is ..)*

The teacher exclaims:

eh?

At this point, the teacher seems to be encouraging the student who has called out, using the exclamation ‘eh?’ as a cue for them to repeat their response to the student at the board. At any rate, the seated student does so, louder this time:

Ni lateral surface (It is…)

At least two other students call out. This is audible:

Surface of base plus lateral surface ….

In this time, the student at the board adds figures to his formula. In the next 10 seconds, the volunteer starts walking back to his seat. Some students call out to him. The following is audible:

OYA OYA lateral surface /unclear/ (*NO NO*)

(Lines 159 -162)

To summarise, I think the teacher’s claim that students help each other in these lessons, and that this is an effective pedagogical strategy is justified. At the same time, his description is partial in relation to the data that we see. The missing element is the teacher’s own decisive role in enabling students to ‘help each other’. For example, in ‘demonstration’ by inviting a student to the board, and guiding them to complete the task directly or by engaging seated students to provide guidance; and where needed by managing the behaviour of other students in the room. Likewise, in ‘questions’, the teacher is a gatekeeper in enabling students to help each other. We see for example, earlier in 7.5, he chooses not to allow a student to offer guidance to the student at the board:

> In the five second pause that follows, the volunteer starts writing on the board. The teacher stands to the left of the room and watches closely, as do most students in the class. In this time, a student calls out:
>
> > S: The surface. the surface. eceka. Ntago ari surface. Bari gushaka /surface/ (*It is not the surface they trying to find)*
> >
> > T: /Mumureke/ Mumureke ariko.. (*Let him try. Let him try..)*
>
> The student at the board turns back to face board work in the middle section.
>
> (Lines153-4)

He apparently intended the student at the board to have sufficient opportunity to try before allowing other students to offer guidance. The point is that the teacher constructs opportunities for students to 'help each other'. It is therefore of concern that the teacher does not talk about his central role in these lessons. Indeed, none of the teachers I speak to at this school talk about their roles in relation to the new curriculum, in their lessons. This suggests that messaging around the new curriculum has been one-sided, with an emphasis on student activity but without the related focus on how teacher's enable and use student participation in lessons. I discuss the implications of this for teacher CPD in Chapters 9 and 10.

8.3 English medium instruction

Next, I turn to the second part of this third main research question to consider how EMI is constructed, by the teacher and students, in these lessons. I begin by reflecting on the teacher and students' attitudes to English and EMI policy. In relation to himself, the teacher expresses a consistently positive attitude towards English. The extract from a recorded interview below, presents a typical comment:

> I like English. Nothing is difficult in using English in class. It is easy for me to use English because my background is French and many English terms are like traducted (*translated*) from French (05.TIT)

His ability to use English as part of his semiotic repertoire in lessons is evident in lessons 1, 2 and 5, 6 when he uses a substantial amount of English relative to Kinyarwanda, compared to other lessons (*Table 3*). The position of these lessons in the sequence of recorded lessons, indicates that the teacher was most likely using more English than on other occasions due to the observers present (Probyn, 2009). In the first two recorded lessons he may have been concerned to show he adheres to the policy despite assurances that the study was not assessing his use of English or an evaluation. This anxiety may have reduced as his relationship with the local researcher developed. The increased use of English in lessons 5 and 6, seems to show his effort to include me, as a non-Kinyarwanda speaker, in those lessons. This finding points to the power of 'the observer' effect, echoing a report by Probyn (2009). Further, it is an important indication of this teacher's extensive and flexible competence in English, similar to the Ugandan teachers in Early and Norton (2014), which suggest that the teacher's construction of EMI in these lessons is more a response to students than a reflection of his own language abilities (8.3.1). This conclusion contradicts the assumption, reported by Pearson (2014) that teachers' proficiency in English is the principal 'problem' of EMI, to be remedied by teaching teachers English. Indeed, as I illustrate below (8.3.1), the teacher's construction of EMI in these lessons shows he is aware of and responsive to the linguistic challenges which these students experience.

A further point to make, is the contrast between teacher and student attitudes to the policy. The teacher does not express a negative view about the policy at any point in our conversations, and neither do other teachers at this school. This resonates with previous studies (Pearson, 2014; van de Kuilen et al., 2020; Williams, 2016). In two separate staffroom conversations, teachers talk about the importance of English as an international language as a rationale for EMI (Fieldnotes, 05.06.18; 06.06.18). Typical comments were made by the mathematics teacher during an early interview:

> English is important for communication. To facilitate communication. English is the first language spoken globally. It is basic to access many things. It dominates other languages globally. It is a tool for personal development (05.TIT)

Similar comments from teachers about the global importance of English as a *reason* for EMI in Rwanda were recorded by Pearson (2014) and van de Kuilen et al. (2020)and echo official statements made about the policy by the Rwandan government (Pearson, 2014)

Like teachers, students do not question or criticise the policy, but in contrast to teachers they give more pragmatic and immediate reasons for learning English; succinctly put by one student:

> Learning English helps us to pass the exams of subjects taught in English
>
> (05.SFGN)

This schism between the teachers' endorsement of English as an international language, and students struggle with learning through English, also resonates with Setati (Setati, 2008). To use Blommaert et al.'s distinction (2005), the teachers' comments index 'global English' while students are concerned with acquiring the 'local English' they need to get through school. As I go on to show in this chapter, this is arguably the English they are getting in these lessons.

A final point to make here, refers to the negative impact that the acceptance of the legitimacy of the policy has a on student self-esteem and motivation. Like teachers, students did not question or criticise the policy in focus groups, referring to it instead as a fact which they have to manage. For example, as one student commented:

> I still have difficulties in English but we must know it because it is the language used in high school so you try your best so you can understand what you are learning. (06.20.SGIT)

As these comments show, students talk about the difficulties and challenges they experience using English. However, as here, they present this as a *personal* problem rather than an issue with the policy itself. This raises a significant problem with the policy, in that it positions students as lacking in relation to the monolingual ideal (as presented, for example, in the coursebook Appendix E and G). The normative power of the policy is evident in comments which the teacher makes, where he states that English is no problem for students:

> (…) students understand what has been asked or written in English. They started learning English in primary (school), they try to be familiar with working in English. I cannot say that the language is a problem because they are now familiar with learning in English. (06.13.TIT)

These comments seem to show that he doesn't consider English a problem for students, because it *shouldn't* be a problem, according to the model of the policy in which students learn English as a subject for three years before learning through English from year 4 of primary onwards (2.3.1). The fact that students need support to access English is presented as a failure of the students and not the policy. This is indicated by the comments made by students during a post-lesson focus group, below:

> S1: The language issue that I had it was to ask questions but it was due the lack of confidence. I did not have enough confidence to ask in English
>
> S3: The issue is the lower level of English skills we have
>
> S1: It is because I cannot match verbs to formulate a sentence.

Mathematics lessons in a government secondary school in rural Rwanda: A case study

> (19.09 SGIT)

Worryingly, these comments indicate that students' negative perception of their own language skills inhibits their motivation to communicate verbally in lessons, and this echoes a conclusion drawn by Probyn (2009) Westbrook and Croft (2015) defined Tanzanian teachers' inclusive beliefs about students, as locating 'challenges' in the interaction between students and their environments and resources, and not as personal 'deficits' of students themselves. Moreover, they suggest that these teachers' inclusive beliefs are linked to their inclusive practices, a finding that is supported by Brinkman (2019). Thus, in addition to limiting students' verbal participation in lessons directly, the deficit perspective on students' abilities fostered by EMI may also undermine the effort this teacher makes to include all students.

Therefore, the linguistic ideology of EMI in Rwanda appears to be a substantial problem, perhaps *the* major problem with the policy. This is because, as I demonstrate, the teacher and students use English to construct and participate in lessons as part of a multilingual and multimodal semiotic repertoire in ways which appear to enable students to access language *and* mathematics. The problem is not student or the teacher's linguistic resources and repertoires or the teacher's pedagogical and linguistic approach, but the monoglossic ideology of the policy.

8.3.1 Teach in English and explain in Kinyarwanda

In order to identify how the teacher and students construct EMI in these lessons, I analyse lesson data in relation to the teacher and students' stated language policies, and language policy discourses at school and in the wider education system (Cincotta-Segi, 2011a; D. C. Johnson, 2011). Indeed, it is striking that the teacher, on various occasions (05.TIN; 06.13.TIT; Fieldnotes 05.09, 06.09) and students, in groups and individually (05.09.SFGN; 19.09.SGIT), describe students' preferred language policy in similar terms. Take for example the teacher's statement in an early interview.

> When I teach I prefer to use English only but students do not understand maths without explaining in Kinyarwanda (…) students like me to use both Kinyarwanda and English (05.TIN)

The teacher's comments here indicate that he is aware of and adapts to students' need for language support and the use of English *and* Kinyarwanda in lessons. Notably, students describe their preferred use of language in lessons in almost exactly the same terms. For example, when groups of students were asked to list the qualities of a good teacher, one group said that a good teacher should:

> Teach in English and explain maths in Kinyarwanda (05.09.SFGN)

On a different occasion, in answer to the question of which language they prefer using in mathematics lessons, one student responded:

> I like studying mathematics in English but with some explanations in Kinyarwanda for understanding mathematics and English too.
>
> (19.09.SGIT)

Interestingly, almost the exact same phrase is reported from a Rwandan primary school teacher working in a rural, government school, in Williams (Williams, 2019, p. 654). The similarity in these stated language policies, may indicate the enacted language policy is also similar in other classrooms. The notions of teaching in English and explaining in Kinyarwanda merits further investigation. On the surface, the comments might be taken to mean that the teacher 'switches' from verbal presentation in English, to verbal explanation in Kinyarwanda. However, a close look at teacher and student comments, and lesson data indicate that English and Kinyarwanda are used flexibly as part of a multilingual and multimodal semiotic repertoire (Garcia, 2009; Garcia & Li, 2014).

There are two main strategies for teaching in English, which the teacher refers to, and which can be seen in the lesson data. The first of these is his approach of beginning instructional units by writing mathematical texts on the board, in 'preparation' (e.g., 6.2 and 7.2). In section 6.2, I discussed the extent to which this approach contrasts with the units in the CBC textbook, which typically begin with student-led and talk-based tasks. I pointed out how the teacher's approach is necessitated by limited numbers of coursebooks, and the 'English only' of the text (Early & Norton, 2014; Milligan et al., 2016). Moreover, it makes sense in relation to the instructional unit as a whole, in which the teacher shows the students the text he has written, in 'presentation'; then guides volunteer students to do an exercise on the board, thus modelling the mathematical process and providing a contextualised example of the general mathematical concept, in 'demonstration'; before highlighting the connection between the abstract and applied mathematical concepts and processes, in 'summary'. Interestingly, the teacher refers to this approach as a strategy to help students access English.

> Students find it difficult to understand spoken English, but when you write it they understand (05.TIN)

The teacher's statement here reinforces the impression that this is a purposeful pedagogical strategy. Seen now in the context of EMI, it indicates that the language in education policy reinforces the teacher's pedagogical approach, and mitigates against his adoption of the approach of the CBC textbook.

A second strategy which the teacher refers to is repetition. For instance, he says:

> For students to understand I repeat it many times (05.TIN)

On the surface these comments suggest that the teacher uses the same language repeatedly, until learners understand. In fact, when we look at lessons, we see the teacher draw on a large and varied semiotic repertoire to 'repeat' the mathematical concept in response to students, by moving across verbal languages (Garcia & Li, 2014) and mathematical modes (O'Halloran, 2015). This was evident in 7.4, 'surface area of a cuboid' when students apparently did not understand how to do the task which was written on the board (see *Figure 16*, below).

Example the net of a cuboid consists of a series of rectangles. How many rectangles are there? What is the surface area of the cuboid if it measure 6 cm by 3 cm by 2 cm? Solution

Figure 16 Board-work at the start of demonstration

Firstly, the teacher drew the 3-D outline of the cuboid on the board (Line 68). Then, he showed the students the 3-D diagram, asking students to tell him how many rectangles the diagram shows (Line 73). Next, he counted the faces of the diagram cuboid on the board, using his chalk and talking aloud:

> Iyi niyi, niyi niyi, niyi niyi yo hasi. Is six. Sibyo? (*This side and that, this side and that, and this side and the one below. Isn't it?)*
>
> (Line 77)

After that, he wrote a formula for the calculation of the three rectangles on the board, talking the process aloud as he did so (Lines 81-2). Finally, he guided students 'step by step' to complete the calculation with him, using dialogue and the written text on the board. He showed students where 'rectangle one' is, and that there are two rectangles on the diagram which are the same verbally ("Rectangle ya mbere ngizi, zirimo ari face ebyiri. Sibyo?" (*The first rectangle is here. There are two faces*) and using gesture. He labelled length, width and height on the diagram. He wrote the equation for the surface area of a rectangle, and indicated this should be multiplied by two, as there are two equal rectangles. He used dialogue to engage students in solving the calculation: “dukubye kabiri ni kangahe? …heh?” (*Eighteen multiply by two, we get*?). Then he wrote the correct answer, which a student provided, on the board (Lines 87-97). After these ‘repetitions’ of the exercise, several students to complete the second calculation in front of the class, an activity which provides a visual demonstration for other students. The pedagogical strategy of repetition is reported by Barrett (2007), Early and Norton (2014) and Westbrook and Croft (2015). However, in the light of the extract presented here, the term ‘repeat’ seems inaccurate. As this extract shows, the teacher moves between forms of representation, drawing on a rich semiotic repertoire of verbal language, mathematical visuals and symbols, and using gesture and dialogue, in response to students, to help these students understand.

In addition to these two stated strategies, there is evidence in lessons of another way that the teacher, systematically, supports students to access the ‘official’ language of lessons. He does this by simplifying the English of the textbook, firstly as he copies text from the coursebook onto the board and secondly, as he shows students the text during presentation. This can be seen ‘frequency polygon’, the instructional unit presented in 6. The text appears in the textbook as follows:

> A histogram is a diagram used to represent frequency distribution in an ungrouped data. A histogram resembles a bar graph or bar chart with the bars touching one another. (Appendix E, p.221)

The teacher which the teacher writes in ‘preparation’ (6.2), is as follows:

> definition: a histogram is a diagram used to represent frequency distribution in an ungrouped data. (*Figure 4*)

This is what the teacher says to students in ‘presentation’ (6.3):

> A histogram .. is a diagram used to represent … the frequency on a graph …
>
> (6.4, Line 4).

Here we can see the teacher ‘grading’ the English that he uses with students, a strategy that appears intended to support them to access the language and the mathematics. In the activities that follow, students see a histogram being drawn and used to make a frequency polygon.

So far in this section, I have presented three strategies which the teacher uses to ‘teach in English’ in these lessons; all three are evident in lesson data, while the teacher refers only to the first two himself. These are; beginning instructional units with written text on the board; ‘repeating’ what the students do not understand using a multilingual and multimodal semiotic repertoire; and simplifying the language of the textbook. The teacher's use of these strategies indicates the extent to which he is aware of, and responds to, students need for language support. Next, I turn to consider what the teacher and students mean by 'explain in Kinyarwanda'.

On the surface, the comment suggests a verbal translation from 'English' to 'Kinyarwanda' but lesson data indicate something far more complex. Firstly, this is because the teacher rarely uses just 'Kinyarwanda' when he is talking mathematically (as opposed to managing student behaviour). This, I suggest, is because in these lessons English is the language of mathematics (8.3.3). Therefore, when the teacher 'explains' in 'Kinyarwanda he uses embedded mathematical terms in English, in what I term 'meshing'. Take, for example, how the teacher ends 'frequency polygon'. As he draws a line to join the marks he has made in the top middle line of each bar on the histogram, he says:

> Iyi line ijoininga midipointi … of this barchart. (*This joins the midpoints*) Niyo twita … (*We call it* …) frequency polygon .. do you understand..?

(Line 70)

In this utterance Kinyarwanda and English are meshed into a single text, which is both transparent, enabling students to access mathematical meaning and visible, enabling them to see the mathematical (English) terms (Adler, 1999; Lave & Wenger, 1991; Setati et al., 2008). The teacher and students use English for mathematical terms consistently, and this blurs the distinction between 'languages' for these terms, which seem to be both part of English and Kinyarwanda. Thus, while this strategy may be described by the teacher and students as explaining in Kinyarwanda, the 'explanation' is multimodal and multilingual. Meaning, moreover, is derived from the previous activities, in which the terms were presented, and the process of making the histogram using the frequency table was demonstrated. I assert, that 'explanation' in these lessons is as much through showing and doing mathematics, as it is about telling. This is reinforced by student post-lesson comments after 'surface area of a cuboid':

I: Tell us what you learnt today?

S5: I was happy today because the teacher gave us good explanations.

I: what did he explain to you?

S5: He explained to us how to find the surface and we have understood.

(09.17.SGIT)

The student describes the strategy that helped them to understand as 'explanation'. The interactions presented in 7.4, and here above, show the teacher 'repeating' the method for calculating surface area of a cuboid in various forms, engaging students to do a calculation as a class, and guiding a student to demonstrate a calculation on the board. In 7.5, we saw the teacher enabling students to express their mathematical thinking, and multilingually and multimodally, drawing parallels between the two methods. Thus, while the teacher and students recognise the importance of 'explanation' in these lessons, they seem to lack the vocabulary to describe it in more detail.

There are two methodological issues which arise with this kind of analysis. Firstly, it is hard to distinguish between linguistic and cognitive challenge (Cummins, 2000), that is, between students' difficulty with English, and their difficulty with mathematics, as the teacher's comments indicate:

> Sometimes some terms are explained in Kinyarwanda but students still do not understand. For example, integral, infinity (…). (05.09.TIN).

The terms which the teacher uses as an example here refer to mathematical concepts, which may be best acquired through participation in mathematical activity (Brown et al., 1989; Chval & Khisty, 2009; J. N. Moschkovich, 2015). Therefore, translation to Kinyarwanda terms is unlikely to be a sufficient strategy on its own to build conceptual student understanding. Student comments suggest that some of the difficulty they ascribe to English may also be mathematical. For example, in a focus group one student commented:

> I faced the language issue because they are some that I could not understand but sometimes teacher was using Kinyarwanda and I could understand something. But some parts were confusing. (06.13.SGIT)

This statement implies that even when the teacher used Kinyarwanda, the student still struggled to understand. The same issue is evident in the comments of the student below:

> I: Did you face the language difficulties?
>
> S: Yes.
>
> I: Where?
>
> S: To find the value of x using 360 degrees.
>
> I: It was difficult?

S: Yes

I: you think that it was because of the language?

S: Yes.

(06.27.SGIT)

It appears that this student ascribes their difficulty to English, whilst their response, formulated algebraically, suggest the issue may have been mathematical. It is hard to untangle challenge which arises from the language *of* mathematics, which I suggest is English, in these lessons (8.3.3) and the mathematics. Conflation of the two is likely to be especially acute at the start of lessons, because of the teacher's decision to begin instructional units with written, English, mathematical texts. The second, related methodological issue is that it is hard to untangle the teacher's response to linguistic challenge from his mathematics pedagogy. The strategies which the teacher uses to enable students to access the language of mathematics, which I have outlined in this section, are part of his 'holistic' pedagogical approach to teaching and learning mathematics. I explore the implications of this, in relation to teacher CPD in Chapters 9 and 10. Next, I consider two specific uses of 'English' in these lessons, as the language of mathematics and as a language of visibility.

8.3.2 English is a visible language

The second claim is that English is used by the teacher and students as a visible resource. This is evident in the teacher's extensive use of English in 'presentation', where, as I demonstrated in section 6.3 and 7.3, his aim is to show students mathematical texts and processes. Take, for example, the teacher's use of 'English' in 6.3:

> He takes a step back, glances at the class, then turns again to face the board, saying:
>
> > A histogram .. is a diagram used to represent … the frequency on a graph …
>
> He steps towards the board with his right hand, holding the chalk, raised. He underlines the phrase 'make a line' as he says:
>
> > and we make a line.
>
> Then he steps back to the side of the board. He is three quarters turned towards the board, as he continues:
>
> > In frequency a polygon is a line …. join all all the frequency on the on the graph

(Lines 4-6)

In this extract his purpose is to show students the written text on the board, which he does by reading it aloud and underlining sections of text. He continues to use 'English' as he draws and labels the histogram, this time he is not 'reading aloud', but directing students to 'see' what he is doing:

> The teacher turns to look at the table that he drew on the left of the board. After a few seconds he turns back to the middle of the board and draws the outline of an X and Y axis in long single strokes. As he finishes the second, horizontal line, he says:
>
> > frequency located on? …
>
> In the three second pause, he glances to the left at the table, and then raises his chalk to the vertical y axis as he says:
>
> > the y axis ….
>
> In the four second pause, he writes the word 'frequency' along the Y axis.
>
> (Line 9)

In both extracts the teacher seems to use English to direct student attention as part of a wider semiotic repertoire, which includes his use of pause and intonation, the text on the board, and the process of doing mathematics. Students also seem to use English for visibility. In particular, when they want the teacher's attention, for example to volunteer to ask a question or to demonstrate at the board. An example of this is seen in 'demonstration' (7.4), when a student is trying to volunteer, a signal which is, it appears, purposefully overlooked by the teacher:

> The teacher continues to look around the room. In the three second pause that he leaves, the student who has his hand up calls out:
>
> > eh teacher!
>
> Again, the teacher doesn't accept. He appears to be keeping the invitation open by moving his gaze around the room, and saying:
>
> > Sibyo? …(*Isn't it?)*
>
> The student with his hand up calls again for the teacher's attention:
>
> > teacher! teacher!

(Line 70-72)

In addition to being a visible language, it appears that 'English' is used to 'point to', or index (Blommaert & Dong, 2010; Fairclough, 2013), two particular and contrasting discourses, these are CBC/learner centred methods and authority. An illustration of how 'English' is used to index the CBC, is in the routine way in which the teacher begins 'demonstration'. Take, for example, the start of demonstration in 7.4

He completes the text by underlining the word 'solution' in a single stroke, then walks to a desk front left. He puts down the coursebook and picks up the set square and holds it aloft.

> Who can come to correct this question? Anyone who can come to correct the answer …Hari uwaza ngo agerageze? *(Who can try*) ….. heh? ….

He points to the example on the board as he says 'this question', then turns to look and gesture out at the class. He moves to the left of the room, and moves his gaze over the students seated there. Students continue writing, chatting quietly or looking across the room.

(Line 67)

It seems that here the teacher is using 'English', along with other semiotic resources, to get student attention in order to begin the next activity. In this sequence, he underlines the word 'solution' at the top of the empty middle section of the board, extends the set square (used in this lesson as a ruler) towards students. After the 'English' utterance, he pauses, and then switches to Kinyarwanda, before pausing again. He points to the exercise on the board, then gazes and gestures at students. All of these cues, I suggest are ways of signalling the beginning of 'demonstration' to students. The teacher's switch to Kinyarwanda here does not appear to be because he is concerned that students will not understand his meaning. This activity is a central part of each lesson, and there is nothing apparently new or ambiguous about its introduction here. The teacher's switch is one of many, in a sequence of cues to students to volunteer.

In addition to the visibility of 'English', the particular 'English' terms he uses point to the teacher's view that this is a 'learner-centred' CBC activity (8.2.2). Across lessons he uses the phrases 'who can come' or 'who can try'; questions 'can you come' or 'can you try?'; and/or occasionally the imperatives 'try' or 'come' to begin this activity. Thus, in addition to 'English' the words 'come', and 'try' point to a particular pedagogical approach.

A further use of 'English' in these lessons by the teacher, is to index authority and arguably a quite different pedagogical approach than that of the CBC. This is evident in his use of 'English' as a tool to direct student behaviour. For example, in 'presentation' in 7.3:

> The teacher writes the label 'height' and then looks up and says:
>
> > are you looking here? ….
>
> Most students turn to face the front. A single student answers audibly and in English:
>
> > yes
>
> The teacher continues looking up and around the room, as he says:
>
> > are you .. looking for this figure? …
>
> In the pause left by the teacher, a single student answers audibly:
>
> > Yes … yes…
>
> The teacher walks towards the right of the room, and says in a low tone:
>
> > Follow …
>
> His gaze moves around students seated on the right as he walks. Students either look at the board or write in their notebooks. Again, a single student responds to the teacher, in the pause:
>
> > Yes …
>
> (Lines 26-31)

The teacher's use of phrases such as do you see, are you looking, look here and the word 'follow' in English and in Kinyarwanda, are emblematic of the teacher's approach of showing students mathematics, himself, and by guiding other students to do so, and the expected behaviour of students which is primarily to look and listen.

In this section, I have shown how the teacher and students use the visibility of English to direct attention, and to index the CBC and authority. As the extracts indicate, these uses of English can be simultaneous i.e., English can be used as the language of mathematics, and visibility and authority. Next, I turn to consider two the factors which appear to be associated with the teacher's construction of English in these lessons.

8.3.3 English is the language of mathematics

The teacher and students consistently use 'English' as the language *of* mathematics in these lessons, and this finding which resonates with Webb and Webb (2008) and Early and Norton (2014). This includes mathematical terms (e.g., frequency polygon) as well as terms used mathematically (e.g., 'point' in 'frequency polygon'), (Schleppegrell, 2007); mathematical registers such as the 'word problem' written on the board at the start of frequency polygon (table shows how a group of 50 students performed in a maths quiz marked out of ten, *Figure 4*); definitions, such as the written definition of a histogram provided in 'frequency polygon' (definition: a histogram is a diagram used to represent frequency distribution in an ungrouped data, *Figure 4*).

This use of English as the language of mathematics is evident in the text that the teacher writes on the board, and which students write in their notebooks which only ever in English. Look, for example, at the text which the teacher writes on the board during 'preparation' in 'surface area of a cuboid' (*Figure 12*):

<u>Unit 7 solids</u>
<u>definition</u>
is a dimension figure that has a flat surface for each face
<u>2.1 Cuboid</u>
definition a solid bounded by three pairs of identical face which are rectangle
(3D diagram of a cuboid, labelled 'face')

Figure 12 Surface area of cuboids board-work

Figure 31, below, taken after the lesson, shows the text which a student has written in their notebook:

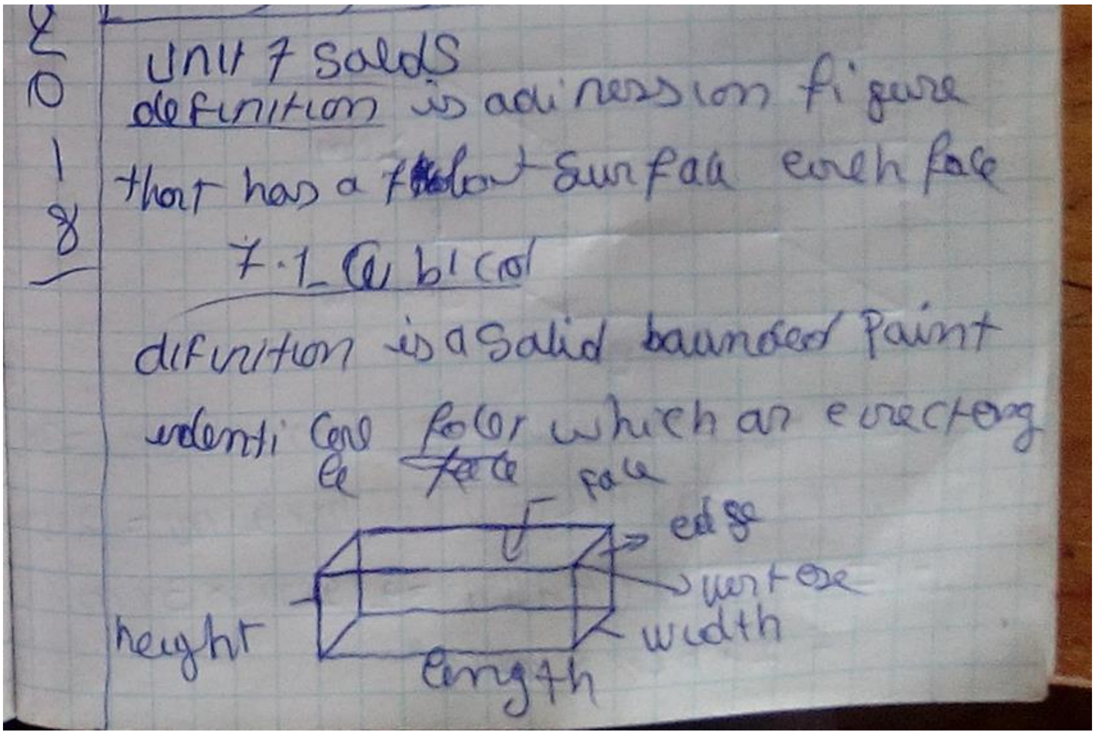


Figure 31 Student notebook

Figure 12, and the photo above in *Figure 31*, illustrate that verbal written text is only ever in English in these lessons, a finding reported by Setati et al. (2008). This, I argue reflects the use of English in these lessons as the language *of* mathematics, along with non-verbal semiotic forms (such as the model cuboid here). It reflects and reinforces the high-status of English in these lessons. I find it notable that Kinyarwanda is not written by the teacher or students in lessons, for example to translate or comment on text, because this contrasts with their use of spoken language in lessons. One ready explanation is that, given the monoglossic ideology of EMI (1.2, 3.2.2), the teacher and students may be concerned that written texts provide a record of transgression of the policy in a way that spoken interaction does not.

Because of the blanket use of English for written texts, the use of English as the language *of* mathematics is perhaps more evident when we consider spoken interaction. Consider, for example, this short extract from 'surface area of a cuboid', in which mathematical terms are in 'English':

> The teacher gestures towards the formula in the middle of the board as he says:
>
>> Nabyo nta kibazo, Sibyo? Ubwo ni, ni total y izi surfaces zose tubonye, Sibyo? *(That's fine too. That's the total of all of these surface areas we got. Isn't it?) ………… (12 seconds)*
>
> (Line 137)

As data presented in 7 illustrate, students also use 'English' as the language of mathematics. In 'questions' (7.5), seated students provide verbal guidance to the student working on the board. For example:

> In the five second pause that follows, the volunteer starts writing on the board. The teacher stands to the left of the room and watches closely, as do most students in the class. In this time, a student calls out:
>
> > The surface. the surface. eceka. Ntago ari surface. Bari gushaka /surface/ (*It is not the surface they trying to find)*
>
> (Line 153)

Later on, the student who is working in the board addresses the teacher:

> The student points to the text on the board, facing the teacher as he says:
>
> > Nagirengo upointed ya total surface cyangwa lateral surface? *(I want to point the total surface or lateral surface?)*
>
> (Line 157*)*

Other student contributions in this section include:

> A seated student, calls out:
>
> > Ni lateral surface *(It is ..)*
>
> (Line 159)
>
> At least two other students call out. This is audible:
>
> > Surface of base plus lateral surface ….
>
> (Line 161)

In the next 10 seconds, the volunteer starts walking back to his seat. Some students call out to him. The following is audible:

> > OYA OYA lateral surface /unclear/ (*NO NO*)
>
> (Line 162)

It is important to emphasise that while I claim that the teacher and students use 'English' as the language of mathematics, the extracts indicate the extent to which 'English' terms are part of a wider multimodal and multilingual semiotic repertoire. I propose the concept of 'meshing' to describe how this teacher uses English mathematical terms, with Kinyarwanda and multimodal semiotic forms to provide access to meaning and the language of mathematics. In addition, being the language of mathematics is far from the only indexicality of English. Next, I consider two "implementational resources" which explain the teacher's language policy in these lessons (N. Hornberger & Johnson, 2007); the teacher's self-identification as a mathematics teacher and not language teacher; and his position that "language is not all that important for mathematics" (Fieldnotes, 04.09).

8.3.4 I am a mathematics teacher and not a language teacher

The first factor, relates to this teacher's professional identity. Comments which he makes in interviews and more general conversations indicate that he identifies strongly as a mathematics teacher, and not an English teacher or a bi-lingual educator (Fieldnotes, 13.06.18; 05.09.18). For instance, this statement, below:

> I am a mathematics teacher, not an English teacher (Fieldnotes, 04.09)

This statement suggests that the teacher's pedagogical focus in these lessons is mathematics teaching, a conclusion which is confirmed by the lesson data. This finding resonates with Setati et al., (2002) who found that secondary teachers were more focussed on subject-teaching than language teaching in multilingual classrooms in South Africa, compared with primary teachers. As I demonstrated in 8.3.1 and 8.3.3 above, in these lessons, the teacher teaches English as the language of mathematics, i.e., to the extent that verbal language is part of mathematics, along with multimodal mathematical forms such as symbols and visuals (O'Halloran, 2015). In contrast, he draws on a wider multilingual and multimodal repertoire *for* teaching mathematics (Barrett & Bainton, 2016), and this is justified because his primary objective is for students to learn mathematics, and not English.

Interestingly, it seems that the teacher uses discourse around EMI as an "implementational resource" to enable himself to take this position (N. Hornberger & Johnson, 2007). For example, in the extended interview he talked at length about the 'failure' of primary school English teachers to teach students enough English (04.09.TIN). He is apparently referring to 'model' of EMI in Rwandan schools, where students learn English as a subject at lower primary before 'transitioning' to learning through English at all other levels (2.3.1). He seems to use the policy to distance himself from responsibility to teach students English, it is instead the responsibility of primary school teachers and a failure of students themselves if they lack English (04.09.TIN). This finding resonates with Setati et al., (2002) who found that primary school mathematics and science teachers felt more pressure to teach students English than their peers in secondary school. This ideology of EMI is further echoed in coursebooks, which are written as if for monolingual English-speaking students (Milligan et al., 2016)(Appendix E and G). Thus, it appears that, somewhat paradoxically, the teacher uses the monoglossic ideology of EMI to distance himself from the policy. He identifies primarily as a teacher of mathematics, and enables himself to use language flexibly in these lessons. At the same time, although he does not state that he is doing it, the teacher frequently provides 'language support' for students to access English. For example, in 'preparation' in 'frequency polygon' (6.2) we saw how the teacher simplified the English of the coursebook in his written text on the board. In 'presentation' (6.3) he supported students to access the meaning by drawing a histogram on the board. Specifically, he provided a translation for the mathematical term "ascending order" (Line 14) into 'everyday English' ("from the lowest to the highest number", Line 16) by gesturing from low to high, and then by numbering the chart in this way.

8.3.5 Language is not that important for mathematics

A second contributing factor behind the teacher's construction of EMI in these lessons, and indeed in relation to his pedagogical approach in general, is his view that "language is not that important for mathematics" (Fieldnotes, 04.09). The instructional units presented in Chapters 6 and 7 demonstrate that verbal language is not this teacher's only, or primary, pedagogical tool. As I showed in 6 and 7, the pedagogical core of these lessons is 'demonstration', in which a student volunteer shows their classmates how to do a practice exercise, which contextualises and exemplifies the mathematical concept-target of the lesson, with guidance from the teacher and/or students when needed, which is also available to the class (6.4), (7.4) The teacher's pedagogical approach is also evident in the objectives that he describes for lessons. Take, for example, the way that the teacher describes the objectives of 'the cuboid', in post-lesson interview:

> T: The objective is to know how to draw a cuboid, what a solid is, and when a solid is called a cuboid. They should know that a cuboid has six sides with three pairs of equal faces. We learnt also how to find to the surface, and that this surface is obtained by using the area of the rectangles obtained in the cuboid and how to find the volume of a cuboid.
> (09.17.TIT)

As this description indicates, 'talking mathematically' is not a pedagogical objective for this teacher. His objective is to enable students to know mathematics through seeing and doing mathematics. This pedagogical approach, finds some foundation in apprenticeship models of mathematics instruction (Brown et al., 1989; Lave & Wenger, 1991; J. N. Moschkovich, 2015), although Moschkovich also makes clear that she sees a central role for talking mathematically in mathematics lessons. To conclude this point, we can say that the teacher does not experience EMI as a significant problem, because verbal language is a part of rather than pivotal to his multimodal pedagogical approach and objectives. Notably however, verbal language, and specifically student talk is a central tenet of the CBC (REB, 2015)(2.3.2). Thus, to the extent that EMI ideology reinforces the teacher's pedagogical approach, we can say that it undermines the teacher's adoption of methods used in the CBC coursebook.

8.4 Chapter summary

In this chapter I presented findings and analysis in relation to the third main research question, which asked: how are the CBC and EMI constructed in these mathematics lessons? To answer this question, I have prioritised the perspectives of the teacher and students in addition to my own observations. The teacher talked about the CBC in positive and general terms initially, which echoed formulations I, and others, had heard from other Rwandan teachers and in official statements (1.4), (van de Kuilen et al., 2020). Later, he indicated he was adapting the curriculum based upon his knowledge and experience of mathematics teaching and learning, and of learner centred methods. The teacher described his lessons as CBC lessons to the extent that students are active in these lessons, and students learn from helping each other. I find substantial evidence to support both claims in lesson data. Notably, however, although student participation in these lessons is enabled by the teacher, and this is something neither he, nor other teachers at school refer to when talking about their implementation of the new curriculum.

The teacher's construction of the policy in these lessons is distinct from the lessons in the CBC textbook. This can be explained in part by the limited numbers of textbooks in lessons (van de Kuilen et al., 2020) and the language of the textbook (Milligan et al., 2016). However, as I argued earlier, there is much more to these lessons than an absence of CBC pedagogy. The teacher's pedagogical approach can be understood in relation to apprenticeship learning (Lave & Wenger, 1991) is seen as relevant for the teaching and learning of mathematics (Brown et al., 1989) in multilingual classrooms (Chval & Khisty, 2009; J. N. Moschkovich, 2015)

The teacher seems to have positive personal attitude to English, and his use of English in specific lessons indicate that he is able to use English extensively and flexibly as part of his teaching (Early & Norton, 2014). The teacher expressed support for EMI policy, which he justified on the basis of English as an international language (Pearson, 2014; Setati, 2008; van de Kuilen et al., 2020;

Williams, 2016). Students accept EMI without question, but with more pragmatic purpose: they report wanting to learn English in order to pass exams. Moreover, students describe some of the challenges of learning mathematics through English (Setati, 2008). The unquestioning acceptance of the policy by the teacher and students, and the monolingual ideology of the policy seems to lead the teacher and students to 'blame' students for lacking English. Students report lacking confidence to ask questions in lessons because of their 'low level' of English (Probyn, 2009). Other studies indicate that teachers' negative attitudes towards students as 'deficient', co-relate with less inclusive teaching practices (Brinkman, 2019; Westbrook & Croft, 2015).

The teacher and students agree on the students preferred language policy, which is for the teacher to teach in English and explain in Kinyarwanda, a formulation which is echoed in Williams (2019). The teacher employs several strategies to teach in English, including beginning lessons with a written text on the board, 'repeating' English multilingually, multimodally and responsively "until students understand", and simplifying the English of coursebook in his written and spoken English. The teacher uses Kinyarwanda, with embedded English, as part of a multimodal semiotic repertoire, which includes students showing each other mathematical meanings and practices, to explain in lessons. I propose the term 'meshing' to describe the way in which the teacher uses English mathematical terms, within multilingual and multimodal utterances, to enable access to the language of mathematics and to mathematical meanings and practices. As Setati (2005) discusses, the use of English as the language of mathematics, visibility and authority in these lessons, reproduces entrenched socio-linguistic inequality and may undermine the extent to which the teacher and students value conceptual discussion. Thus, while the teacher's approach to 'meshing' English and Kinyarwanda is pragmatic and pedagogically effective, it may serve to reproduce the political status quo.

It is difficult to separate linguistic and cognitive challenge in these lessons (Cummins, 2000)and indeed, the teachers' strategies for teaching in English and explaining in Kinyarwanda are part of his overall construction of lessons (6.6). It is notable that some of the teacher's strategies for teaching in English reinforce his pedagogical approach and undermine that of the CBC coursebook. The 'English only' of the coursebook makes the text inaccessible to students without teacher mediation (Milligan et al., 2016). The teacher and students use English in these lessons as the language of mathematics (Webb & Webb, 2008), and a language of visibility to direct attention (Probyn, 2009), to signal the CBC, and authority (Setati, 2005)and as part of a multilingual and multimodal semiotic repertoire (A. M. Y. M. Y. Lin, 2019; J. N. Moschkovich, 2015; O'Halloran, 2015). The teacher uses EMI ideology to position himself as a teacher of mathematics, and not a language teacher; and to support his view that "language is not that important for mathematics", which aligns with his current pedagogical approach but contrasts with the approach in the CBC coursebook.

The analysis presented in this chapter, indicates the difficulties of investigating the construction of curriculum and language policy separately, and as separate from this teacher's pedagogy which is itself a response to material and social conditions. This analysis points to some of the convergences and divergences between these two policies as they are constructed by the teacher and students as part of these lessons. In Chapter 9, I discuss the implications of these findings in relation to the literature and with regards to teacher CPD in Rwanda and comparable contexts, before concluding the thesis in Chapter 10.

9 Discussion

9.1 Introduction

Now, I discuss the findings of this study, in relation to the concepts and research introduced in Chapter 3 and Chapter 4. I indicate the ways in which this study resonates with and builds on previous work, the contribution it makes and the questions it raises. The chapter is structured into three main sections, which correspond to the three main research questions of this study (1.3). Each of these sections is further sub-divided, based on the main claims presented in Chapters 6-8.

9.2 The teacher's construction of lessons

9.2.1 Purposefully, to achieve mathematical-pedagogical objectives

In Chapter 6, I demonstrated how the teacher constructs these lessons purposefully, to achieve particular pedagogical objectives in response to his subject and the context of this classroom, using extracts from an instructional unit 'frequency polygon'. Across lessons, instructional units begin with the teacher writing selected mathematical texts from the coursebook onto the board, in English, which students copy into their notebooks (6.2, 7.2). The teacher presents the texts to students, and the mathematical objectives of the lesson (6.3, 7.3). In 'demonstration' the teacher invites a student to complete the example on the board, providing a performance of a mathematical practice and an example to ground the abstract mathematical concept, for the class. The teacher provides guidance to the student working at the board where needed, and engages other students in the class to do so, and these 'scaffolds' are available to the class (6.4, 7.4). The teacher closes instructional units by showing students connections between the example which has been performed for the class and the mathematical concepts and text with which he began the lesson (6.5). He often invites students to asks questions, as a means to close the instructional unit, and in response to signs from students that they require further clarification (7.5).

The teacher's pedagogical approach can be understood in relation to apprenticeship learning (Lave & Wenger, 1991), as he engages students in the performance of classroom-mathematical practices, such as reading mathematical texts (6.3, 7.3) and completing mathematical exercises (6.4, 7.4). Students are able to be part of the 'full practice', and there is opportunity for their participation to progress from the periphery to the centre as they work in their notebooks, or demonstrate to the class on the board (Lave & Wenger, 1991). The approach of teaching mathematical concepts through engagement in mathematical practices finds support in the literature (Brown et al., 1989) and specifically in relation to the teaching of mathematics in multilingual classrooms (Chval & Khisty, 2009; Moschkovich, 2015). The analogy of apprenticeship learning is compatible with performance-mode pedagogy (Bernstein, 1996), to the extent that both focus on the performance of defined practices. Given that performance-mode is the dominant pedagogical mode in classrooms in SSA (Guthrie, 2018), apprenticeship learning may be a useful 'lens' for further investigation and development of mathematics teaching and learning in Rwanda, and comparable contexts.

It is evident that the teacher's construction of the policy in these lessons is distinct from the lessons in the CBC textbook. This can be explained in part by the limited numbers of textbooks in lessons (van de Kuilen et al., 2020) and the language of the textbook, which mean that the teacher needs to mediate the text for students (Milligan et al., 2016). However, as this thesis demonstrates, it is worth looking beyond the 'model' of pedagogy in the textbook and the absence of this in lessons. There are several distinct aspects of pedagogical quality in these lessons which relate to constructivist learning principles (Chisholme & Leyendecker, 2008; Schweisfurth, 2013, 2015). The teacher observes and responds to students in these lessons; the teacher acts to engage students in lesson activity; the teacher uses relevant examples to 'ground' abstract mathematical concepts and practices for students; and the atmosphere in the classroom is collegial, and respectful. These findings resonate with several other studies cited in this thesis: (Barrett, 2007; Early & Norton, 2014; van de Kuilen et al., 2020; Westbrook & Croft, 2015). Specifically, the 'performance-mode' pedagogical approach of these lessons (Barrett, 2007; Bernstein, 1996) and the use of 'demonstration' as a pedagogical strategy (ibid.; Westbrook & Croft, 2015). These findings indicate the need for further engagement with situated pedagogies, to inform textbooks, and teacher CPD that engages with, and supports teachers to develop, their practice.

A strong argument for doing so, is the extent to which this teacher's pedagogical approach appears to be responsive to a range of contextual factors, which would seem to inhibit the adoption of the 'learner-centred' methods of the textbook. These include the number of students in the class; the number of available textbooks; the language of textbook relative to students' linguistic resources; time constraints; exam pressure; and national curriculum and language in education policies. This list of significant contextual factors, resonates with the findings of other studies in Rwanda and similar contexts: (Altinyelken, 2010; Barrett, 2007; Early & Norton, 2014; van de Kuilen et al., 2020).

This study indicates the utility of looking beyond 'pedagogical mode' to examine the teachers' construction of classroom practice, in interaction with and in response to students and a range of contextual factors. This 'interactionist approach' (Schweisfurth, 2015; Westbrook & Croft, 2015), has enabled me to look beyond practice as a problem, to focus on interactions: between the teacher and students, and the teacher and context. The central, agentive role of the teacher in constructing 'these mathematics lessons' reinforces calls for teacher CPD which engages teachers in the process of learning and development in relation to their current beliefs and practices and social and material contexts (Barrett, 2007; Brinkman, 2019; Early & Norton, 2014; Westbrook & Croft, 2015).

9.2.2 Using multilingual and multimodal semiotic resources

The second main claim which I presented in Chapter 6 is that the teacher uses multilingual and multimodal semiotic resources to construct these lessons and to communicate mathematically. This finding resonates with the concept of translanguaging (3.3.1) and a substantial number of studies of classroom practice in multilingual contexts (Cincotta-Segi, 2011a; Early & Norton, 2014; Probyn, 2009, 2015). The present study contributes by highlighting the central role of non-verbal semiotic forms in classroom communication. The finding is significant, indicating that researchers should include non-verbal linguistic resources in their data and analysis of classroom communication; and further, indicates the need for sustained and detailed explorations of classroom interaction in order to identify situated forms and meanings.

The present study provides detail on the teacher's systematic and flexible use of linguistic resources. The teacher consistently uses 'English' for mathematical terms and register (Schleppegrell, 2007) and this resonates with earlier findings (Early & Norton, 2014; Setati, 2008, 2003; Webb & Webb, 2008). He uses English, as a 'visible' language (Adler, 1999; Lave & Wenger, 1991; Setati et al., 2008) for mathematical terms and registers (Schleppegrell, 2007); and to signal authority (Setati, 2005, 2008), to signal the CBC, and to gain, maintain and direct student attention (Probyn, 2009). He uses English as part of a broader multilingual and multimodal semiotic repertoire, and combines 'English' with 'transparent' linguistic resources, to make mathematical forms, meanings and practices accessible students (Adler, 1999; Lave & Wenger, 1991; Setati et al., 2008). I propose the term 'meshing' to describe this practice, of combining visible and transparent linguistic resources in single utterances. This finding resonates with the language as a resource orientation taken by Setati et al. (2008), Probyn (2015) and Moschkovich (2002; 2015) and indicates that 'English' does not present problems of proficiency, when it is used flexibly by teachers and students as part of a multilingual and multimodal semiotic repertoire.

It is notable that the integrated ways in which the teacher uses his semiotic repertoire in this study contrasts with proposals for linguistic practices in multilingual classrooms. For example, the 'pedagogical journey' proposed by Setati et al. (2002)Figure 3), which portrays distinct 'languages' and registers as separate steps of the journey. It also differs from the proposed model of "pedagogical translanguaging" (Heugh et al., 2019; Makalela, 2015, 2019; Probyn, 2015), which promotes the separate use of 'languages' with the aim of bi/tri -literacy. One apparent reason for the difference here, is that this teacher's aim is to teach mathematics and not language. This is evident in his statement of lesson objectives e.g., 6.2, and his statement that he is a mathematics and not a language teacher (8.3.4). He teaches English only in so far as it is part of mathematics, as the language *of* mathematics (Barrett & Bainton, 2016; Early & Norton, 2014), along with other semiotic resources/mathematical modes (O'Halloran, 2015). He uses Kinyarwanda as a 'transparent' language *for* teaching and learning, along with other semiotic resources (Barrett & Bainton, 2016; Setati et al., 2008). Thus, pedagogical translanguaging may not be appropriate in this classroom, because this teacher is aiming to teach mathematics and English as part of mathematics and not literacy in two languages. This finding resonates with Jasper's call for classroom language policy researchers and advocates to appreciate the complex concerns which teachers' work with, beyond their concern with verbal language and literacies (Jaspers, 2018). At the same time, I find that the teacher uses language systematically and responsively in relation to his pedagogical aims. It is systematic, in the shared policy of 'teaching in English and explaining in Kinyarwanda' 8.3.1), his use of English as a visible resource (8.3.2), and the consistent use of English as the language of mathematics (8.3.3). It is responsive, in that the teacher flexibly 'meshes' modes and shifts between modes, to enable students' access to language and mathematics. As such, the teachers use of multilingual and multimodal semiotic resources is an indicator of pedagogical quality in these lessons (Barrett, 2007; Schweisfurth, 2013, 2015).

This study indicates the limitations of prescribing 'ideal' linguistic practices to teachers, as like pedagogy, linguistic practices are sensitive to specific contexts of use. The study indicates the need for additional research in multilingual mathematics classrooms in Rwanda and comparable classroom contexts, to identify practices (such as, 'meshing'), which may be applicable.

9.2.3 Through routines and by responding to students

The third and final main claim, is that the teacher constructs these mathematics lessons through routines and by responding to students. It appears that the familiarity of routine activities means they can be signalled, set up and managed with minimal verbal instructions. As reported by Bernstein (1996) and Barrett (2007) this appears to be a means of saving time preparing lessons and during lessons. Therefore, the use of routines is appropriate in settings with short lesson periods in strictly defined timetables, and where teachers have limited time to prepare lessons (ibid.). In addition, this study indicates that the use of routines enables students to be active in co-constructing and at times leading activities, whether this is by performing expected behaviours, or, as we see in ‘demonstration’ (6.4, 7.4) by subverting them. This finding suggests that routine activities do not only restrict classroom communication, as suggested by Alidou et al. (2006) but can also be a resource for classroom communication. This reflects the insight from CR, that social structures are the conditions for social action and interaction: they constrain and enable communication and can be reproduced and transformed in interaction (3.2).

The findings from this study, that the teacher uses routines and responds to students, resonates with Barrett’s (2007) application of Bernstein’s (1996) pedagogical models (*Table 2*) in her analysis of classroom practice in Tanzania (2007) Barrett found that lessons were overall in the performance mode but, within this mode, teachers continually observed and responded to students. Likewise, I find that these mathematics lessons are overall in the performance mode, and that the teacher responds to students in this mode. He is most responsive to students during ‘demonstration’ and ‘questions’, activities which he constructs with students in the lead. Notably, the data from this study indicate that routine and responsive elements of these lessons work together as part of ‘holistic’ instructional units (5.7.2). For example, the highly routine activities of ‘preparation’ and ‘presentation’ enable ‘demonstration’ and ‘questions’ to proceed. This finding indicates the importance of investigating lessons in pedagogical wholes, and not drawing conclusions from the analysis of parts.

This study confirms the insight that teacher and student agency are not binary qualities, but are closely inter-related (Alexander, 2001, 2015; Schweisfurth, 2013, 2015). This is significant, given reports that that learner-centred pedagogy is interpreted in Rwanda as the teacher doing less, and ‘groupwork’ (van de Kuilen et al., 2020). It suggests that rather than learner centred or even learnING centred pedagogy (Brinkman, 2019; O’Sullivan, 2004), ‘teaching and learning’ centred research, policy and teacher CPD programmes may be more appropriate.

9.3 Students participate in lessons

9.3.1 Using multilingual and multimodal semiotic resources

The first main claim which I presented in 7, is that students participate multilingually and multimodally in these lessons. This finding resonates with other studies of classroom interaction in multilingual contexts which point to the range of linguistic resources that students use to communicate in multilingual classrooms (Early & Norton, 2014; Setati et al., 2008). Like the teacher, the students use English, as part of a wider multilingual and multimodal semiotic repertoire, as a language of visibility (7.4, Line 71-2), and the language of mathematics (7.5, Line 153).

This study finds that student verbal participation in lessons is extremely limited, and this confirms previous reports (Erling et al., 2017)This study contributes to understandings of student participation in Rwanda, and comparable contexts, by demonstrating that student participation is often non-verbal and multimodal. In these lessons, students participate by facing the board and writing in their notebooks (6.3, 7.3), and by completing mathematical exercises on the board, performing or watching the demonstration, and providing guidance to the demonstrator (6.4, 7.4).

The emphasis on students looking, listening and showing reflects the teacher's pedagogical approach to teaching mathematics (6, 9.2.1) and the teacher's stated view that "language is not that important for mathematics" (Fieldnotes, 04.09, 8.3.5). For example, in 'questions' the teacher asks students to show their methods rather than describe them (7.5). Student-talk is a resource which appears to be under-used in these lessons. Nevertheless, as noted above, the teacher's extensive use of multimodal forms and practices in lessons seems to be appropriate for the teaching and learning of mathematics (Brown et al., 1989) and specifically in multilingual classrooms (Chval & Khisty, 2009; Moschkovich, 2015). It is therefore problematic to equate dialogic pedagogy only with "high quality talk" (Schweisfurth, 2015, p. 264), when, as we see here, students participate and the teacher responds to students using non-verbal *and* verbal linguistic resources.

The implications of this finding for researchers of classroom practice in SSA are significant. The majority of studies reported in this thesis primarily rely upon analysis of verbal lesson data (Altinyelken, 2010; Barrett, 2007; Probyn, 2015). Instead, the findings of this study suggest that investigations of student participation should account for non-verbal as well as verbal semiotic forms, and their situated use.

9.3.2 In ways which are more and less controlled by the teacher

The second main claim which I make in 7, is that students participate in ways which are more and less controlled by the teacher. This claim reflects my observation that student participation differs across activities. For instance, in 'preparation' (7.2) the teacher does not interact directly with students, and students choose when to write the text from the board into their notebooks which is arguably and opportunity to self-differentiate the level of challenge. In 'presentation' (7.3), student participation is closely controlled by the teacher, who uses a range of semiotic resources to direct their attention to the text on the board and the tasks for the lesson ahead. In 'demonstration' (7.4) student affordances increase: through the act of volunteering, or not; for the student volunteer, who leads the activity which follows; and for students who offer support to the student working at the board (e.g., 6.4). During 'questions' (7.5), student participation is constrained by the rules of the activity. However, within these routine forms there are considerable affordances for students to express their thinking. As we saw in 7.5, student action in 'questions' leads the teacher, who responds to students and positions his preferred method in relation to their own. As this summary indicates, student participation in these lessons and teacher action are closely connected. This is perhaps clearest during 'preparation', when the teacher does not engage with students directly, and this limits the extent to which students access mathematical texts and activities. The finding confirms the conclusion of a number of researchers that teaching and learning are interconnected processes (Alexander, 2001), (Alexander, 2015), and that social structures and relationships enable and constrain classroom communication.

Therefore, efforts to increase student participation in lessons should focus on teacher as well as student behaviour, and more importantly, on pedagogical interactions. This conclusion echoes comments made by Setati et al. (2002), who conclude that groupwork is not a "panacea" for pedagogical quality (4.3). Student participation is not simply and absence of teaching, and does not 'naturally occur' when teaching is withdrawn. The finding is significant given the emphasis on groupwork and the absence of discussion about the teacher's central role in enabling student participation in conversations about the CBC in Rwanda (van de Kuilen et al., 2020) (Fieldnotes, 03.09; 04.09; 05.09).

9.3.3 To co-construct and at times lead interactions and activities

The final main claim which I make in relation to student participation is that students co-construct and at times lead lesson interactions and activities. The finding that students co-construct lessons reflects the insight that lessons are constructed by participants in interaction (3.2.3). The findings of this study suggest that, even when it appears that students are behaving passively, their behaviour (verbal and non-verbal) serves to co-construct lesson activities. My claim that students 'lead' interactions and activities, refers to the central role of the volunteer student in 'demonstration' when the teacher stands aside, and observes and responds to the student (6.4, 7.4). As noted above, this affordance is constructed by the teacher, who continues to manage this activity. However, the mathematical practice is student-led, and the teacher observes and responds to the student at the centre of the action. Another example of when students lead and the teacher responds to students is student questions (7.5). These activities, managed by the teacher with students in the lead, enable students to express their mathematical thinking, constructed by the teacher. Lemke (1990) discusses the importance of teachers enabling students to express their thinking and responding to students' ways of making sense of science, noting that that this is rare in science lessons in the USA, based on his substantial research experience (pp. 43-6).

The variation of student participation, in form and extent, across activities indicates the importance of considering interactions across what I term 'instructional units' (5.7.2) i.e., complete pedagogical sequences from the perspective of the teacher, rather than making claims about classroom practice based on sub-units (e.g., activities or parts of activities). For example, analysis of 'presentation' (6.3, 7.3) out of the context of the full instructional unit may have led me to conclude that student participation in lessons is limited to "safe talk" (Alidou et al., 2006). A further issue that may contribute to negative descriptions of classroom practice in SSA, is the extent to which student participation in these lessons is non-verbal. Thus, studies which evaluate student participation on their verbal contributions e.g., (Probyn, 2015), may be partial in their coverage. Moreover, the tendency of researchers to look for learner-centred pedagogies as norms of quality e.g., Setati et al., (2008), Webb and Webb (2008), and Probyn (2015), as reported in Schweisfurth et al. (2020), may also have meant that alternative practices have been overlooked.

9.4 The construction of the CBC and EMI in these lessons

9.4.1 The CBC in these lessons

With regards to the construction of the CBC in these lessons, I found that this mathematics teacher, and other teachers at school, initially talked about the new curriculum as a 'switch' from knowledge-based to competence-based pedagogy; simplistic and binary terms, which echo official discourse (MINECOFIN, 2000; MINEDUC, 2013; REB, 2015). In later conversations, the teacher provided a more nuanced account of his "recontextualization" (Bernstein, 1996), (3.3.2) of the new curriculum. However, notably, his descriptions remained one-sided: he talked about students being active (8.2.1) and students helping each other (8.2.2), but he did not talk about his key role in enabling student participation in these lessons; and neither did other teachers at school. In a recent study in Rwanda, van de Kuilen et al. (2020) report that all teachers associate the new curriculum with groupwork, which the researchers find is ill-suited to the material conditions of the lessons they observe (in relatively well-resourced schools). The present study seems to confirm that messaging around the learner-centred pedagogy and the new curriculum in Rwanda has been too simple and one-sided and this may fail to engage teachers with improving, and may even undermine, teaching and learning.

I find that the teacher agentively "recontextualises" the CBC as part of his pedagogical approach (Bernstein, 1996), (3.3.2) using the "implementational resources" available to him (Hornberger & Johnson, 2007). In interview, the teacher talks about students being active and helping each other in these lessons (Fieldnotes, 04.09; 06.09), and these descriptions are confirmed in the data (8.2.1, 8.2.2). A methodological point to note here is that, the connection between these lessons and the CBC became apparent through analysis of lesson data in combination with the teachers' account of his lessons. This resonates with Barrett (2007), who initially thought that teachers' descriptions of their lessons as learner-centred was misleading, but later came to see aspects of learner centred practice integrated in the lessons she observed. The present study extends Barrett's analysis by pointing to some of the factors which inform this teacher's recontextualization of the CBC in his lessons. The teacher refers to having learnt about LCE as part of his bachelor of education at university, and this appears to contribute to his confidence interpreting the CBC to be relevant to his subject and his students (Fieldnotes 09.04). The extent to which this secondary mathematics teacher "recontextualises" the CBC, aligns with Van de Kuilen et al. (2020) who found that Rwandan secondary school teachers are more likely to maintain an instructional role in lessons, compared to primary school teachers. It suggests that initial teacher education might be a decisive factor, as Rwandan secondary teachers tend to be educated to degree level, and like this teacher, often have bachelors of education, while the primary teacher qualification is the equivalent of upper-secondary school (A-Levels) (Williams, 2016).

The finding that teacher CPD impacts teachers' practice resonates with Barrett (2007), who found that teachers who had attended teacher CPD related to child rights tended to treat children more equally; and Westbrook and Croft (2015), who attribute the inclusive pedagogical practices of Tanzanian teachers to apprenticeship periods with more experienced teachers at school, among other factors. Setati et al. (2002) and Webb and Webb (2008) found that the CPD interventions their studies evaluate also impacted practice. Setati et al. (2002) came to question the pedagogical value of groupwork, which was readily adopted, and Webb and Webb (2008) indicate substantial challenges in introducing exploratory talk within groupwork. The findings of the present study, in conversation with the findings of these other studies, lend support for Brinkman's (2019) conclusion that teacher CPD should engage teachers with the principles of LCE, and enable them to develop locally relevant pedagogical approaches.

It is notable that the teacher deviates from the CBC lessons as portrayed in the textbook in his minimal use of groupwork and student-talk based activities. This is an important insight in relation to conversations around textbook use in Rwanda. Milligan, Clegg and Tikly (2016, p. 335) report that the language of mathematics and science textbooks in Rwanda makes them inaccessible to students. The data from the present study confirm that language of the textbook may be a barrier for students, by pointing to the various ways in which the teacher mediates the language of the book for them (8.3). In addition, data indicate that the pedagogical approach of the textbook, which is distinct from the teacher's approach (9.2.1), is another reason why the teacher mediates the coursebook for students. Therefore, in order to increase use of the coursebook both linguistic and pedagogical barriers need to be bridged. As I noted above (9.2.1) the data suggest that the teacher's pedagogical approach is an appropriate response to teaching mathematics in this context. It is therefore important to understand this teacher's pedagogy as a whole, rather than evaluating it as lacking, through the lens of policy ideals.

9.4.2 EMI in these lessons

Finally, I consider the teacher and students construction of EMI in these lessons. As I noted above (9.2.2 and 9.3.1) in these lessons the teacher and students use English, as part of multilingual and multimodal semiotic repertoires, to construct and participate in lessons and to communicate mathematically. This finding aligns with a large number of studies in multilingual classrooms (Probyn, 2009; Setati et al., 2002; Webb & Webb, 2008). In these lessons, English is consistently used as the language of mathematics (Webb & Webb, 2008). In addition, I find that the teacher and students use English as a "visible resource" (Lave & Wenger, 1991; Setati et al., 2008) to gain, maintain and direct attention (Probyn, 2009), to assert authority (Setati, 2005, 2008) and to index the CBC. These findings point to the range of situated meanings constructed by the teacher and students using English, and resonate with understanding of how language is used 'interdiscursively' as part of complex social systems (Fairclough, 2013; 3.2.1, 3.2.2). In Chapter One, I noted that a common critique of EMI is that teachers and students lack the language *proficiency* to teach and learn through English (Alidou et al., 2006; Milligan et al., 2016; Schweisfurth, 2013). These claims can be traced to Cummins's (Cummins, 1980, 2000) work with language minority students in Canada, and I query the application of this theory to multilingual classrooms in SSA. The data from this study suggest that proficiency in English is not a problem, because the teacher and students use English as part of their multilingual and multimodal semiotic repertoires (9.2.2, 9.3.1). I proposed the term 'meshing' to describe the way in which the teacher integrates English mathematical terms and register with multilingual and multimodal semiotic resources, and enables students to access English (and other mathematical forms), and mathematical concepts and practices. The data from this study suggest that access to mathematical English, is not dependent on ‘everyday English’, but is provided through Kinyarwanda and other semiotic forms. Indeed, this observation resonates with another of Cummins’ theories, that of Common Underlying Proficiency, which provides for the transfer of knowledge between semiotic modes (Cummins, 2017). It also resonates with the idea of psycho-linguistic competence as a single integrated system (Garcia & Li, 2014; Herdina & Jessner, 2002; Jessner, 2017). The distinction is important because the view that teachers’ limited proficiency in English is the problem with EMI, drives national teacher CPD programmes in Rwanda (Pearson, 2014; Williams, 2016). This is problematic, in that the “basic and generic” English of these courses (Pearson, 2014, p. 46), does not reflect the multilingual and context specific ways in which teachers use English in the classroom. Further, it risks enforcing the monoglossic ideology of the policy, which does appear to have serious consequences for teaching and learning (8.3, and below).

A further critique of EMI is that it restricts teachers’ pedagogy, by undermining the flexible use of talk in lessons (Alidou et al., 2006; Ouane & Glanz, 2011). The data here indicate that the teacher’s pedagogy is a holistic response to a range of contextual factors, including the subject of instruction, class size and time constraints (9.2.1). Therefore, it is too reductive to point to EMI as “the problem” (Alidou, et al., 2006, p. 14) of pedagogy in SSA. Indeed, the characterisation of pedagogy in SSA as a problem may reflect the application of inappropriate pedagogical and linguistic ideals in research (2020) and teacher CPD (2.3.1, 2.3.2), which I critique in this study. That said, EMI ideology may reinforce the teacher’s beliefs that language is not that important for mathematics (8.3.5), and groupwork in not suitable for mathematics (8.2), thus reinforcing his pedagogical approach and undermining the intended lessons of the CBC coursebook.

It is notable that the teacher uses the “ideological resource and space” (Hornberger & Johnson, 2007), of EMI to position himself as a mathematics and not a language teacher. It is important to recognise that this teacher is not aiming to teach students bi-literacy in English and Kinyarwanda: he teaches English to the extent that it is part of mathematics (8.3.3). This finding contrasts with reports by Adler (1995) and (1999), Setati et al. (2002), Setati (2005) and Probyn (2009) and (2015). The South Africa teachers in these studies see themselves as responsible for teaching English and mathematics, and experience a series of tensions and dilemmas as a result. For example, between teaching mathematics and teaching English, and between their languages of identity, and English as a language of power and social mobility. The difference between the experience of teachers in these two contexts can be explained by South Africa’s multilingual language policy (Probyn, 2009), in comparison with Rwanda’s monoglossic policy (Pearson, 2014).

Thus, the findings of this study, indicate the limitations of applying insights between distinct socio-linguistic contexts.

The insight that this teacher is not aiming to teach bi-literacy, provided by the present study, is important for two reasons. Firstly, it indicates the way in which monoglossic ideology is used as a resource to enable multilingual classroom practice by this teacher. This raises questions around whether a switch to a multilingual language policy, in which Kinyarwanda and English are treated as parallel languages in the classroom, would benefit the students and teacher. Secondly, it calls into question the recommendation that teachers in multilingual classrooms across SSA be trained in “pedagogical translanguaging” (Banda, 2018; Makalela, 2019; Probyn, 2015). The English that is used in these lessons, by the teacher and students, is limited. It is the language of mathematics (8.3.3) and a language of visibility (8.3.2). This English is, as Blommaert et al. note (2005), far from the English of international mobility, which is presented as a reason for the introduction of EMI in Rwanda (2.3.1), and described by teachers at the school as a reason for EMI (8.3). It is however, far closer to the English which students report desiring, which is the English that they need to pass exams and to get through school (05.SFGN, 8.3). Although Early and Norton (2014) point to ways in which local English, perceived as sub-standard by national standards, can lead to students being marked down in examinations.

There is a strong case that the monoglossic linguistic ideology associated with EMI in Rwanda (2.3.1), disadvantages teachers and students in the classroom and beyond. For instance, in Chapter 2, I cited reports that teacher CPD has been dominated by generic and basic training in English language for teachers (Pearson, 2014; Williams, 2016). This training is unlikely to meet the needs of teachers of different subjects and grades, or connect with teacher’s multilingual (and multimodal) classroom practices. Another example can be seen in the secondary mathematics coursebook (Appendix E and G), which is written as through for monolingual speakers of English and therefore inaccessible to the majority of students (Milligan, Clegg, & Tikly, 2016). Another serious cause for concern is the extent to which EMI ideology reinforces negative perceptions of student competence by the teacher and by students. The teacher and students appear to accept EMI policy unquestioningly (8.3). Therefore, the ‘problems’ of EMI (i.e., the distance between students’ linguistic repertoires and the monolingual ideal of the policy) are blamed on students’ lack of ability or effort. Students report that they lack confidence to ask questions in English during lessons (09.19.SGIT). Westbrook and Croft (2015) and Brinkman (2019) demonstrate connections between teachers’ attitudes to students and their classroom practices, indicating that EMI ideology may undermine teaching and learning in Rwanda. Finally, the systematic use of English as the language of mathematics, visibility and authority in these lessons with Kinyarwanda as a language of transparency reinforces entrenched socio-linguistic inequalities, whilst providing a pragmatic pedagogical solution.

This study suggests the need for researchers to move beyond seeing EMI as a problem only, and primarily a problem of proficiency, to consider the various meanings of English, and the ways in which teachers and students use English to communicate. A valuable task may be to record, share and validate examples of multilingual classroom communication to challenge the persistence of monoglossic ideology in Rwanda and elsewhere. It reinforces the need for teacher CPD to engage with actual resources and objectives of teachers and students rather than generic pedagogical and linguistic methods. Finally, where this is possible, it indicates the importance of engaging teachers with the political dimensions of classroom language in order to challenge socio-linguistic hierarchy, whilst enabling students to access languages of power.

9.5 Chapter summary

In this chapter I reflected on the findings of this study, in relation to previous work. I highlighted connections with previous work, and the contribution that this study makes and the implications for teacher CPD and research. In Chapter Ten, I conclude this thesis with a summary of key findings, the contribution of this study and recommendations for further research and teacher CPD in Rwanda and comparable contexts, and reflecting on the limitations of the study and what I have learnt from it.

10 Conclusions and recommendations

10.1 Introduction

I conclude this thesis with a summary of findings which connect to previous work, and contribute new insights, and by making recommendations for teacher CPD and research in Rwanda and comparable contexts. These conclusions are presented in four main sections, in relation to research design (10.2); insights about pedagogy (10.3); language use (10.4); and the construction of policy in these lessons (10.5 and 10.6). Finally, I reflect on the limitations of this study, and, in the closing comments, on my personal process of knowledge construction (Blommaert & Dong, 2010).

10.2 Research design

The design of this study reflects other studies reviewed in Chapter Four in the use of case study (Altinyelken, 2010; Duff, 2008; Setati et al., 2002; Westbrook, 2009) to investigate pedagogy as a unique, complex and situated phenomenon. Likewise, the methods of data collection in the present study (i.e., recorded lessons (5.6.1); interviews and focus groups with the teacher and students (5.6.2, 5.6.3, and 5.6.4); and participant observation at school (5.6.5) are consistent with the other studies presented in this thesis.

This study builds on previous research, which combine ethnographic and critical approaches to conceptualise pedagogy as agentively constructed by the teacher, using contextual resources and constraints in ways which reproduce and transform social relationships and processes (Cincotta-Segi, 2011b, 2011a; Johnson, 2009, 2011; Martin-Jones & da Costa-Cabral, 2018). The study contributes to this work, by proposing critical realism as a means to distinguish between socio-linguistic phenomena and other social objects, processes and relationships (e.g., ideology and postcolonialism).

The present study stands out in relation to other studies reviewed here, for its focus on a series of lessons in a single class (5.5). Further, the exploratory approach to the analysis of lesson data (5.7.2), used in early classroom talk and discourse studies in the UK and USA (Lemke, 1990; Mercer, 1995) is not found in the studies reviewed here. This exploratory approach has enabled me to move beyond normative models of pedagogy and language use and contributed to the insights generated by this investigation.

This study confirms the importance of looking beyond normative models of pedagogy and language in explorations of classroom practice (Schweisfurth et al., 2020) and the gains of detailed linguistic analysis of classroom interaction. Further exploratory research into classroom practice in distinct contexts (i.e., school location, type, level and instructional subjects) in Rwanda and comparable contexts is recommended, to inform understandings of pedagogy, and teacher CPD.

10.3 Pedagogy in these lessons

This study indicates the central and agentive role of this teacher in constructing classroom practice, in interaction with students, context, and observers (Schweisfurth, 2015; Schweisfurth & Elliott, 2019). These lessons are predominantly in the 'performance-mode' and this is related to the social and material context of these lessons (9.2.1), (Barrett, 2007; Bernstein, 1996). Pedagogy is 'hybrid', comprising routine and responsive elements (Altinyelken, 2011; Barrett, 2007). Interaction in these lessons reflects key constructivist pedagogical 'qualities' (Chisholme & Leyendecker, 2008; Schweisfurth, 2013, 2015). The teacher observes and responds to students (9.2.3) (Barrett, 2007; Early & Norton, 2014; Lattimer, 2015; van de Kuilen et al., 2020) uses relevant examples of abstract mathematical concepts (6.2, 7.2), (Early & Norton, 2014; Westbrook & Croft, 2015); and creates a collegial and respectful atmosphere (van de Kuilen et al., 2020). The teacher uses 'demonstration' as a pedagogical strategy (6.4, 7.4), (Barrett, 2007; Early & Norton, 2014; Westbrook & Croft, 2015).

This study indicates that routine aspects of lessons enable student participation, and teacher and student agency are inter-related (9.2.3). Opportunity for student participation in mathematical practices are constructed by the teacher in these lessons (9.3.3). Lesson interaction and activities are constructed using multilingual and multimodal semiotic resources (9.2.2, 9.3.1). This study provides detailed description of 'demonstration', which I suggest is central to this teacher's pedagogical approach (6.4, 7.4) and analyse in relation to apprenticeship learning (Lave & Wenger, 1991; Moschkovich, 2002).

More exploratory research into classroom practice is needed to counter negative discourse about teaching and learning, and inform policy and teacher CPD in Rwanda and comparable contexts. The agency of teachers, and the particularities of distinct classroom contexts, confirm the need for teacher CPD that engages with teachers existing beliefs and practices, and the principles and practices of proposed changes (Brinkman, 2019; Early & Norton, 2014; Westbrook & Croft, 2015)

Student participation, and the inclusion of all students in classroom practice (Westbrook & Croft, 2015) are key principles which can be used to direct further research and teacher CPD.

10.4 Language in the lessons

The teacher and students communicate using a multilingual and multimodal semiotic repertoire (9.2.2, 9.3.1), (Early & Norton, 2014; Garcia & Li, 2014). The teacher uses language as a 'visible' and 'transparent' resource to enable access to the language of mathematics, and mathematics concepts and practices (Adler, 1999; Lave & Wenger, 1991; Setati et al., 2008).

Teachers' use of multimodal semiotic resources is mentioned in a number of studies (Barrett, 2007; Probyn, 2009) but is peripheral and not central to researchers' description or analysis of classroom practice. In contrast I find that the teacher and students' use of multimodal semiotic resources, along with verbal language, is central to communication in this classroom.

I propose the term 'meshing', to describe how 'English' is used, as part of a broader multilingual and multimodal semiotic repertoire, to make mathematical forms, meanings and practices accessible to students. Specifically, 'meshing' refers to the combined use of 'visible' and 'transparent' multi-modal linguistic resources in single utterances. The term does not pre-suppose that linguistic resources belong to distinct 'languages', and is therefore more appropriate that code-switching when language users are not using the indexicality of 'languages'. At the same time, it highlights the material qualities of language (i.e., more or less visible or transparent) and thus adds nuance to the term translanguaging (Garcia & Li, 2014) . This study indicates the limitations of "pedagogical translanguaging" (Makalela, 2015, 2019; Probyn, 2015) in this classroom context, where the teacher's and students' aim is not to develop bi-literacy in two languages. It is important to retain recognition of the political dimension of language use. Whilst meshing is a pragmatic, pedagogical response to EMI, the systematic use of English as for mathematical language, and as a language of visibility and authority reproduces socio-linguistic hierarchy. Teacher CPD should include reflection on the political dimension of language use.

The importance of non-verbal multimodal forms identified here suggests that researchers should look beyond verbal language when documenting and analysing classroom interaction. Further research is needed to detail and analyse language practices as part of pedagogy in multilingual classrooms. Such research can inform teacher CPD that reflects, and enables teachers to develop, situated language practices.

10.5 The construction of the CBC in these lessons

The lessons which this teacher constructs are considerably distant from the lessons in the CBC textbook (6.2). The distance between LCE ideals and classroom practices is noted by Altinyelken (2010), Barrett (2007), and Webb and Webb (2008), among others. Nevertheless, as noted above, these lessons indicate several key aspects of constructivist pedagogy (10.3.1). The CBC is "recontextualised" substantially by this secondary teacher in relation to his subject, students and contextual resources and constraints (Barrett, 2007; Bernstein, 1996; van de Kuilen et al., 2020).

This study provides detailed examples of how this teacher incorporates 'active learning', and 'students helping each other' in these lessons (8.2.1, 8.2.2). It indicates that the teacher's knowledge about LCE, gained at university and developed in practice (8.2) enables him to meaningfully interpret the CBC.

Research into LCE as part of classroom practice should focus on constructivist pedagogical principles, such as proposed by Schweisfurth (2013) and (2015) (i.e., responsive teacher and student interactions (Barrett A. , 2007); student engagement, inclusion and participation (Westbrook & Croft, 2015); and relevance of subject matter to students) and not only look for 'ideal' pedagogical models (e.g., 'exploratory talk'). Teacher CPD should build teacher understanding of LCE principles, and support them to explore and develop these principles as part of their classroom practice and document and share their strategies (Brinkman, 2019).

10.6 The construction of EMI in these lessons

EMI is partial in these lessons (9.4.2). The teacher and students use 'English' as a visible language (8.3.2); as the language of mathematics (8.3.3) (Webb & Webb, 2008); and a language of authority (Setati, 2008, 2003); and the CBC (8.3.2). This teacher does not lack proficiency in English (8.3) (Early & Norton, 2014). This study indicates that student participation is not limited by their lack of English *proficiency*, because they communicate using a shared multilingual and multimodal repertoire (9.3.1). This teacher sees himself as a mathematics and not a language teacher (8.3.4). This enables him to include English as the language of mathematics (8.3.3), as part of the multilingual and multimodal repertoire (9.2.2) to teach mathematics and English as part of mathematics. This teacher does not appear to experience a 'dilemma' between teaching English and teaching mathematics, unlike South African teachers, who are tasked with teaching language and their instructional subjects e.g., Adler (1995) and (1999), Setati et al. (2002), Setati (2005) and Probyn (2009) and (2015). His aim is not to develop students' literacy in two languages, but may be better understood as developing students' 'academic literacy in mathematics' (Moschkovich, 2015) , which he does through the integrated use of multilingual mathematical semiotic resources and practices.

Monoglossic ideology is a considerable problem in these lessons, where it undermines the utility and use of textbook, teacher and student attitudes towards students' ability, and students' verbal participation in lessons. Further, although the teacher provides considerable language support for students in these lessons, because he does not see himself as a language teacher, he does not talk about it, and this undermines the extent to which these key approaches can be developed and shared. Multilingual classroom communication reinforces socio-linguistic hierarchy to the extent that English is the 'high status' (academic, visible and authoritative) form. The teacher and students hold negative attitudes towards the students' proficiency in English (8.3) and this undermines student confidence and participation in lessons (Probyn, 2009).

Further research into teaching and learning in distinct language policy contexts is needed to document multilingual and multimodal classroom practice, and the ways in which classroom practice reproduces and/or transforms social hierarchies. Teacher CPD should promote positive perceptions of multilingual classroom practice as a means to learn English and mathematics, and support teachers to describe and develop language supportive strategies as part of their subject-pedagogy. Further, teacher CPD should highlight the political dimension of language and enable teachers to agentively re-dress socio-linguistic hierarchy. Advocacy with policy makers, education sector staff and communities is needed to build understanding of and support for the multilingual classroom practices which enable language and content learning. There should be more overt discussion about 'monoglossic ideology' as an anachronistic, inaccurate and unjust set of assumptions which undermines educational quality and equity. Practical steps should be taken to promote better theories of language and multilingualism, such as translanguaging (3.3.1), in teacher education and CPD, and in textbooks.

10.7 Limitations of this study

My engagement with the teacher and students, and with other staff and students at this school was limited. This is reflected in the scarce consideration of institutional (school-level) relationships and discourses (e.g., between teachers of different subjects and established practices and beliefs at school) which would have enriched my analysis considerably. In addition, I regret that I was not able to have more time with the teacher and students, in order to explore their perspectives further and involve them more directly in asking and answering research questions. This was due to limitations on my side, as a self-funding student with a small child, and concerns about intruding on the teacher and students' time. There is considerable scope for further analysis of the data set, and specifically the language and pedagogic practices in these lessons both from more 'linguistic' and 'education' points of view. For example, the different 'meshing' strategies the teacher employs, such as using Kinyarwanda pre- and suffixes with mathematical 'English' words (e.g., 6.5, Line 69). It would be fascinating to explore the extent to which this mathematics teacher's linguistic practices are echoed in other classrooms, and in 'mathematical talk' outside the classroom. A further limitation, was my lack of Kinyarwanda which has meant that I have been reliant on translators and unable to identify nuances in translation. That said, working with local researchers has been enriching, although I limited collaboration because of the need to maintain sole ownership of this study. However, in future I hope to be part of more trans-national and trans-lingual research partnerships.

10.8 Closing comments

I began the study passionate about the power of research to inform project design and development. I wanted to develop my research skills, to inform my future work in project management and evaluation. Over the course of this study, I have shifted from the stance of a consultant, seeking to understand and evaluate practice in line with policy recommendations, to that of a researcher, asking more fundamental questions about what is meant by 'teacher CPD', 'teaching and learning mathematics', 'language', 'multilingualism' and 'policy'. My understanding of these fundamental concepts has transformed through my interaction with the literature, and the data, and these two aspects of the study in interaction. In addition, the experience of designing, conducting and writing up this study has transformed my understanding of what research is, the power and limits of social research, and how I read the research and the use of research-based claims by others. I found the process of looking at what was happening in this classroom, instead of what was 'missing' (from my point of view) challenging and, ultimately, illuminating. Finally, I am back to considering how the insights of this study can inform practical recommendations for teacher CPD, in the policy context of Rwanda. The process of research has been humbling. I have worked at the fringes of my own ability and understanding and become aware of how much I don't know. I have learnt from other researchers, and the teacher and learners in this class and others at the school, and the unfailing encouragement of my supervisor. As I had hoped initially, I have developed my ability to conduct and learn from research, and to share learning with others.

Appendix A National teacher development framework

(Attached as a separate document)

Appendix B Participant information sheet (student)

UNIVERSITY OF Southampton

Participant Information Sheet: Students

Study Title: Language use and learning in a lower-secondary mathematics class in Rwanda
Researcher: Rachel Bowden
ERGO number: 40206

Please read this information carefully before deciding if you want to take part in this research. If you are happy to participate you will be asked to sign a consent form. If you would like more information to help you decide please email me: rb1d15@soton.ac.uk

Who are the researchers?

Rachel Bowden is the lead researcher. Rachel is a student at the University of Southampton, UK. Rachel is assisted by xxxxxx and xxxxxxxx, students at the University of Rwanda, College of Education

What is the study about?

This research project is for Rachel's PhD, looking at English as the medium of instruction in Rwanda. I want to explore how English and other languages are used in class and why, and how this impacts student learning of maths and English.

Why have I been chosen?

Your head teacher and teacher have agreed to be part of the study. As a student in the maths class, you will also be included unless you or your parent/guardian do not want to be involved.

If you agree to be part of the study, I will ask you to:

- Read a consent form, and sign if you agree with the statements, or show what you disagree with. Tell your parents about the study and ask if it is okay for you to take part. Invite your parents to attend an information meeting and/or give them a consent form to complete.
- Attend a group discussions with me or a research assistant to talk about how you use language at school, in lessons and out of school.
- Allow me to observe and video and audio record 10 maths lessons, over six months
- Attend a group discussion after each observed lesson to share your opinion on the best use of language in the lesson.
- Take part in a final group discussion at the end of the study to talk about your involvement the study.

The results of this study will be shared with your school and the Ministry of Education in Rwanda.. The study will be written up in my PhD thesis and may be published as part of academic articles.

Are there any benefits? You may benefit from the chance to think about how you use language for learning in maths lessons. We will share the positive examples we gather through the study with other teachers and students at school so they may also benefit.

Are there any risks? Taking part in the study will take some of your time, but you will not miss any lessons. I will not include your name, address or other information which can be used to identify you in any reports of the study. Information collected during this study will be stored on a password protected computer and will only be used for the purpose of ethically approved research studies. *No information which can be used to identify you, your school, the teacher or students will be included in any reports of this study.*

If you agree to take part we will ask you to sign a consent form. If at any point you **decide you don't want to continue**, you can inform me, Dr Uworwabayeho or the research assistant. If you want to **report concerns or complaints** during the study you can contact me, Dr Uworwabayeho and/or the Research Integrity and Governance Manager at the University of Southampton (0044+23 8059 5058, rgoinfo@soton.ac.uk).

Thank you for taking the time to read the information sheet and considering taking part in the research.

20.04.2018 Version 6 Ethics/IRAS number: *40206*

Appendix C Consent form (teacher)

UNIVERSITY OF Southampton

CONSENT FORM: Teacher

Study title: Language use and learning in a lower-secondary mathematics class in Rwanda

Researcher name: Rachel Bowden
ERGO number: 40206 **Date and Version Number: 27.04.2018 Version 1**

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet 20.04.2018 version 3 and have had the opportunity to ask questions.	
I understand that no information to identify me, my school, or students will be included in research reports.	
I understand that my involvement will not take me or students away from scheduled lessons.	
I agree that up to 10 mathematics lessons may be observed and video recorded.	
I agree to meet with the researcher/research assistant *at a time that suits me* after each observed lesson to discuss positive examples of language use.	
I understand that comments I make may be included in reports of the study but my name will not be used.	
I agree to assist in informing students and parents about the study.	
If parents do not consent for students to be included in recorded lessons I agree to assist in finding a solution that ensures students do not miss lessons.	
I agree that data from the study can be used in reports to the school, the Ministry of Education, the researchers' PhD thesis and academic publications.	

Name of participant (print name)	Name of researcher (print name) RACHEL BOWDEN
Signature of participant	Signature of researcher RACHEL BOWDEN
Date	Date 27.04.2018

20.04.2018. Version 4. Ethics/IRAS number: 40206

Appendix D Transcript: Frequency polygon

The recording of the lesson begins with the teacher writing on the board. He holds the coursebook in his left hand as he writes, and occasionally stops to look at it. He does not talk or visibly communicate with students during this time. Students are seated. Most are copying text from the board into their notebooks as the teacher writes. Some students are talking together quietly or looking around the room.

8.5.6 Histogram and Frequency polygon

definition: a histogram is a diagram used to represent frequency distribution in an ungrouped data.

- a frequency polygon is a line graph drawn by joining all the mid point of the top of the bar of a histogram

example: table shows how a group of 50 students performed in a maths quiz marked out of ten

marks	1	2	3	4	5	6	7	8	9	10
f	2	2	11	11	12	7	4	1	0	0

a) Represent the information in a graph

b) draw a frequency polygon

Board work at start of the lesson (far-left third of board)

Line / time	Teacher	Student	Observations (description)
1	*Genda unzanire ibikoresho bya geometry urabibona muri murisalle …. (Can you please bring to me the geometrical instruments?)* *Irati. Uzane irati gusa. (A ruler. Only a ruler)*		The teacher stops writing after 2 minutes and 56 seconds and moves to the left side of the room, near the door. He talks to a student seated there, so quietly that the request is recorded on the student microphone only. The student stands and leaves the room. The teacher glances after the students outside the door, and then closes the door. He turns to the board.
2	We are going to see what is a histogram.		The teacher moves towards the board as he talks. He traces his chalk along first line of text 'definition' as he talks.
3	A histogram .. is a diagram used to represent … the frequency on a graph …		He takes a step back but still faces the text he has written on the board.

4	and we make a line. In frequency a polygon is a line …. join all all the frequence on the graph …		He steps towards the board and underlines the phrase 'make a line' as he reads it out. Then he steps back to the far left of the board and continues talking. He is still facing the board, as if he is reading the text from the board. After he says 'graph' he moves towards the middle section of the board with his right arm aloft, ready to write.
	as you have to see on this .. example ……..		Teacher writes and underlines the word 'Solution' at the top of the middle section of the board. He turns to look at the table that he drew on the left of the board. After a few seconds he draws the outline of a x and y axis graph on the board in long single strokes.
5	frequency located on … the y axis …..		The teacher writes the word 'frequency' on the y axis.
6	and ….. the marks		Teacher rubs out the X axis line he drew.
7	*…4…6…7…9……* ten …..		He redraws the x axis line and labels the x axis with numbers from the table on the board. He steps between standing in front of the table on the left third of the board, and the graph he has drawn in the middle. His back is to the class. The teacher mic picks up that he softly talks to himself - in English, saying the numbers as he writes them down - 4, 6, 7 and 9, 10. 'Ten' is audible to the class, and the teacher takes a step back. He looks again at the table on the left of the board, and begins to number the y axis.
8	*No rush. There. Ntakibazo (No problem)*		A student enters the room by the door on the left. The teacher stops writing and turns to the door as it opens. He takes a large yellow protractor from the student, and addresses him quietly. The student shuts

			the door and moves to his seat. The teacher keeps the protractor in his hands. He looks at the far-left section of the board.
9	If you write the frequency …		The teacher points to the table drawn on the left side of the board with the protractor. He holds the protractor in his left hand, so that his body is half-turned to the class. He looks up towards the class as he finishes talking.
10	we write on? .. ascending order. Sibyo? *(Isn't it?)* …..		He steps towards the middle of the board, still facing the class as he says 'we write on?'. As he says 'ascending order' he uses the protractor to signal the length of the y axis, moving from the bottom to the top. he looks up at the class as he says 'sibyo'. He turns to look at the table on the left of the board, so that his back is again to the class.
11	from the lowest to the highest number ………. ………. ………. ……….		He continues to label the x axis, looking between the table on the left of the board and the graph so that his back is to the class. The teacher takes a step back, to the left of the board. From the direction of his eyes and the protractor he is still holding, he seems to be reading the two tasks written below the table.

	………. **……….** (60 seconds)		
12 (06:30)	Who can come .. to make .. a frequency polygon…		He looks up to the class as he begins to talk. He retraces one of the lines of the table as he says 'frequency polygon'
13	Anyone to try…		The teacher looks up and turns towards the class, he holds the chalk aloft.
14	Ntawaza ngo agerageze (*Who can try) ……….*		The teacher stands at the left of the room facing the class. There is no sign of volunteering from students. Most continue to look at the board and write in their notebooks.
15	Iushyize izi data kuri graph ugashushanya ya polygon twabonye (*We use these data to draw the polygon we have seen)* **……….**		The teacher moves towards the middle of the board, pointing to the graph with the protractor which he holds in his left hand so that he is half facing the class. As he talks, a student seated at the back right of the room raises his arm and clicks his fingers. The teacher looks up, and signals with the chalk to a student at the back who has volunteered. the boy stands and moves towards the front. The teacher points to different cells of the table as the boy comes forward, as if he is calculating for himself. The student moves towards the teacher. He lifts his hand to receive the chalk, which the teacher then gives him.
16	You start from zero ………. ……….		The teacher faces the student as he says this. He hands the protractor to the student then moves to pick up his copy of the student coursebook from a desk on the left side of the room and then stands to the side. The student puts the protractor down on the same desk at the front left, then glances towards the teacher. He stands to the left of the middle section of the board, and glances between the table on the

	………. ………. …. (44 seconds)		left and the chart. He begins to mark dots on the chart, outlining bar shapes. He turns to look at the teacher. He then draws over the dots as a thick line. He turns to the table, and points with his finger to the second column, then begins to draw it on the graph.
17	using this ruler …		The teacher steps forward, puts his book down on the desk and hands the protractor to the student. The student takes it and uses it as he begins to draw the lines for the second bar on the chart.
18	*for this .. this* .. the student who has two ... are two …ok ……..		The teacher stands in front of the table, and points to the first column as he talks first very quietly and then louder. The boy working in the middle looks over and drops the protractor as the teacher's volume increases. The teacher lowers his voice then takes a step back. The student finishes drawing the second bar, then looks back at the table. He gestures with his right arm extended to the graph
19	student who has three are? eleven …..		The teacher stands to the left side of the board so that he is facing the student volunteer and half facing the class. He speaks slowly and clearly. The volunteer responds by raising the protractor and beginning to draw the third column.
20	Subireba se! sibyo ra? Abagize atatu ni cumi n'umwe. Abagize ane ni cumi n'umwe…………. (*Do you see that? Isn't it? Those who got three are eleven. Those who got four are eleven)*		teacher addresses the student at the board quietly. He is telling him what to write. Innocente (the observer) goes over and says a few words to the teacher.

21 7.47 (video)	Are you looking? .. Kuki mutavuga ariko? Nimurebe . erega ni ukwerekana frequence kuri grafe. Sibyo? (*Why are you talking? Look it is about showing the frequency on the graph. Isn't it?)*		The teacher speaks as he moves to the right of the room. He stands at the right and addresses the students there.
22		yes	Several students answer chorally.
	warangiza ugahuza umurongo….Biragoye? Kandi biriya bintu twarabibonye. *(Then you join with line segment…. Is it difficult? We have seen that)*		The teacher stands in the middle of the room facing the right. The student at the board continues to plot the graph.
23	Noneho tugiye kubibona ukoresheje frequency polygon … *(We now going to see them using frequency polygon)*		Teacher turns to look at the board.

24	a frequency polygon is a line of graph joining the middle point of the top of the bar … or the histogram…Sibyo? ..		The teacher moves a few steps forward and stands looking at the board. He reads the sentence aloud from the left-third of the board, and moves to stand the left of the board. as he says 'histogram' he touches the word on the board, and looks up at the class as he says 'sibyo?' (isn't it?)
25		yes	One student quietly responds
26	Ni ukuvuga ngo turiya dutriangle twagiye dushushanya turipresentinga frekwence ..NITWO TUZA JOININGA *(Isn't it? It means we connect triangles which represent the frequency.)*		The teacher faces students on the right of the class. He raises his left arm and then the coursebook (which is in his right arm) alternately as he speaks, and speaks emphatically.
27		Yego. Yego (yes)	A few students answer
28	MURI KUBIBONA? *(Do you see that)*		The teacher walks through the middle of the room, towards the back. He speaks loudly.
29		Yes!	A single student, loudly.

30 (09:38-09:50)	Turiya dutriango twagiye…dushushanya Turiya ari kugenda ashushanya muri midipoint zatwo turagenda duhuzemo umurongo umwe… Line of graph .. do you understand? *(Those triangles we drew… We join them with straight line from the midpoint)*		The teacher remains at the left side of the room. He continues talking sternly, loudly and moves to the back left of the room.
31 (8.52 video)		yes	A single student quietly
32	….. continue! ………. ………. …..		The student at the board is looking towards the right of the room, as if someone there is talking to him. The teacher seems to see that the student has paused. He speaks loudly from his position at the back left of the room. The student working at the board completes the fourth bar of the bar chart. he steps back and looks again at the table. The seated students are mostly watching the student at the board.
33	Is it correct? Birangana neza ra? *(Are they equal?)* Is it the same?		The teacher walks to the front of the room, to the graph that the student has drawn. He is talking as if he is addressing the whole class, not just the student at the front. The student at the board takes a step back.

34	Iyi triangle yakagombye kuba ingana n'iyi. Igiza hino ntacyo (*This triangle should be equal to that one)*		The teacher points at and between the third and fourth bars of the bar chart with his chalk as he talks. The fourth bar is slightly wider than the third, although they represent the same number.
35	..Sibyo? *(isn't it?)*		He steps to the left-side of the room and looks up at the class and raises his chalk as he talks.
36	…..Bisibe bingane (*Make them equal)*		The teacher stands at the left, watching the student who begins to draw the next bar. The teacher moves over to the board as he talks.
37	..clean! ………. (10 seconds)		The teacher picks up a cloth from the floor and wipes the board. He traces a replacement line with his finder on the board then moves to stand at the left side of the class again. The student at the board begins to redraw the line.
38 (11:01- 11:04)	Hmm! is it equal? Wabonaga zingana? *(Do you think they were equal?)* ………. ………. ………. ………. ………. (50 seconds)		The teacher stands at the far left of the class and seems to address the class. The teacher remains standing at the side of the room. The student at the board redraws the lines and continues to work.

39	..Ariko gira vuba Do quick. Buriya ntari kudukereza ra? Ntawihuta? *(Do it quickly. You are wasting our time)*		The teacher looks at the student working at the board, then walks across the middle of the room towards the right.
40		/unclear/	A few students respond
41	Uwihuta nagende amugirire *(I need other who is very fast)*		The teacher stands by the window on the right of the room, facing the student at the board.
42	……….	yego /unclear/	The volunteer stops and looks towards the teacher, as if he is unsure whether this is the end of his turn. It is not the student at the board who speaks.
43	Draw! ………. ………. ………. ………. …….. (48 seconds)		The teacher looks at and signals the student volunteer with his arm as he speaks. The student at the board turns back to the board and continues with the chart. Looking between the table and the chart. The teacher looks at the coursebook, still standing by the window on the right of the room. The rest of the class are quiet. Most are watching the student at the board.
44	*Uhm! Tugeze kuri element ya kangahe? (We are on which element?)*		Teacher moves to the front to stand next to the student at the board. As he moves he talks to the student quietly.

45		/unclear/	The student at board answers
46	*Umh? ..... Komeza uzane hino. Ugeze aha. (Continue until here)*		The teacher traces along the y axis with his finger as he speaks to the boy, quietly.
47	.....Karindwi afite mo kangahe? Ariko ko mutamubwira ibyo yandika. (*Seven occurs how many times? Please tell him what to write.)*		The teacher moves to the left of the board, and faces the table drawn there. The volume of his voice increases as he continues to talk. He points to the table with his finger.
48	....	Kane! *(four)* four. Kane (four)	Several students answer. The teacher stands to the left of the board. He looks over the class.
49 (13.44)	Karindwi has? *(seven has)*		The teacher looks over the class
50	……… ………	four. Four	several students answer. The student working at the board continues without acknowledging the exchange. He continues working drawing neat and careful lines.
51	Noneho umunane se wo ufite kangahe? (*What about eight?)*		The teacher stands at the far left of the room looking at the coursebook. He looks up towards the class as he talks.

52		Rimwe! Rimwe! (one. one) ………. ………. ………. (30 seconds)	Several students answer. Most students are now copying the graph from the board. Many talk to each other but quietly so that individual turns are indistinct. The teacher remains at the far-left of the room, looking through the student book. The volunteer at the board completes the sixth bar, then looks over to the table again.
53	Icumi ho ifite zero ….. *(Ten has a frequency zero)*		The teacher looks up from his book at the student volunteer. After he has spoken, he moves towards the board.
54	Ababonye icyenda nta n'umwe. N'icumi nta n'umwe…. *(Nine also has a frequency zero. Ten is zero)*		As he talks the teacher takes the chalk from the student, who follows the teacher's gesture and hands it to him. The teacher begins to draw the chart. The volunteer takes a step back and puts the protractor down on the desk at the front left and crosses the room to go back to his seat at the far right of the room.
55	look here ……..		The teacher takes a step back, looking into the coursebook. His back is to the class but he speaks in a loud voice. He takes a step towards the chart, and raises his chalk.
56	Urabona izi triangle. *(Do you see these triangles?)* Are you looking for this? Doo! murareba? *(Are you looking?)*		He turns to half-face the class, marking the chart with the chalk in his right hand. he looks up to the class as he says 'triangle'. He makes a dot with the chalk on the top-middle line of each bar, from left to right.

57	Hano ni midipoint of this triangle. Sibyo? ..Muri kubireba? *(Here it is in the midpoint….isn't it? Do you see that?)*		Teacher looks up at the class as he says 'midipoint' *(midpoint).* He continues to make a point with the chalk on the middle of the top line of the remaining bars.
58		Yes ….	One student answers quietly
59	Nitujoininga ..izi point tugakora line..*(If we join these point with a line.)*		Teacher continues working on the chart. He looks up as he says 'point' and 'line'
60	Sibyo? .. *(Isn't it?)*		Teacher looks to his left, at the text on the left third of the board.
61	Muri kubireba? *(Do you see that?)*		Teacher begins to draw a line between the 'midpoint' dots on the top of each bar. He doesn't turn to the class.
62		yego ….*(yes)*	A single student answers. The teacher continues to draw.
63	Iyi line ijoininga midipointi … of this barchart. *(This joins the midpoints)* Niyo twita *… (We call it …)* frequency polygon .. do you understand?		Teacher continues to draw the line as he talks. He doesn't turn to the class.

64		yes..yes ………. ………. ……. (27 seconds)	A few students answer. The teacher finishes drawing the line. He takes a few steps back and looks at what he has drawn. He steps forward again and draws a line with an arrow on the end from the frequency polygon. He writes the label 'frequency polygon'. He walks back to the left, and then to the front right of the room.
65 (16.43 (video, 15.45)	Hari ufite ikibazo? … *(Who has a question?)*		He picks up a piece of chalk from a desk on the front right of the room, and walks to the right side of the board.
66	Ufite ikibazo … kuri frequency polygone …..hari ufiteho akabazo? Iii? *(Any question ….about frequency polygon? Is there anyone who has a question?)*		The teacher stands at the right side of the board, and looks down into his copy the coursebook as he talks.
67		Yeee *(yes)*	A single student answers
68	Ngaho mbwira (*Tell me).*.		

69		Iriya ntigira izina? *(That graph doesn't have a name?)*	
70	Ihh? ..		The teacher looks up, towards the student who has asked the question.
71		Iriya ntigira izina? /unclear/ *(That graph doesn't have a name?)*	
72 (17:18-17:20)	/None se/ siyo yitwa frequency /polygon/? *(It is called frequency polygon)*		
73		/Polygon/ Polygon. Polygon…..	The student who asked the question repeats the word polygon. Another student repeats 'polygon'. The student who asked the question continues to talk for a few seconds, but what he says is unclear. The teacher looks up at him again.

		(unclear)	
74	Izi ngizi tuba twashushanyije rectangle ni za bar chart sibyo? (*These rectangles we drew are called bar charts. Isn't it?)*		The teacher moves towards the chart, pointing with his right arm extended.
75	…..	Eeeh!	The teacher moves his extended right arm up and down six of the rectangles in turn. The student who asked the question responds.
76	This example show the highest number lowest number sibyo? Urabibona? *(Isn't it? Do you see?)*		
77		Eeeh!	The student who asked the question responds.
78	Nk'aba bagize?.... Ababonye atanu… Sibyo? (*These people got? Those who five are the most. Isn't it?)*		The teacher remains by the chart, tracing the bars with his chalk as he talks.
79		yes	A few students answer

80	Nibo benshi.. (*They passed)*		Teacher turns to face the class.
81	sibo benshi? *(did they pass?*		Teacher raises his chalk in the air as he steps to the right side of the board.
82		Yes yego *(yes)*	A few students answer
83	Urabona ko iriya test barayikoze … (*You can see that the test was well done)*		Teacher stands at the right of the board, holding the coursebook. He looks up at the class and then over to the chart.
84	Buriy Bayitsinze murugero? rwiza? Cyangwa barayitsinzwe? *(The success was on average level. Or they have failed it?)*		
85		Barayitsinze *(They passed it.)*	A single student answers
86	Barayitsinzwe? *(they have failed it?)*		

87	……….	Barayitsinze Barayitsinze. *(They passed it. They passed it. They passed it)*	Several students answer. The teacher remains on the right of the board, looking at the chart as the students answer.
88 (18:09-18:12)	Agiye ninde waza akankorera mean? …. who can come to calculate the mean? …. *(Who can find the mean?)* hari uwakora mean ngo turebe ko batsize? Yariya manota *(Who can find the mean to see if they succeeded?)* Iii? …..		He turns to the class. He looks over the class as he talks.
89	mean! Simuyizi se ukuntu bayicalculatinga? Bayicaliculaatinga gute?		The teacher walks to the middle of the board and begins to write, below the chart, as he talks. He writes the formula X = total marks over total frequency

	(What? Mean? Don't you know how to find the mean?)		
90	ninde waza akayikora? ….. hmmm? Ariko byadusaba gukora .. other frequency table … sibyo? *(Who can find it? But you will to find another frequency table.)*		Teacher moves to the left, to stand in front of the table. He looks at the table, and then turns to the class as he says 'hmm?'. He looks up again as he says 'other frequency table'
91	Alice wagerageza? *(Alice can you try?)*		He looks at a female student seated on the front left of the room. he extends his arm with the chalk in it and moves towards her. She extends he arms and takes the chalk. She stands slowly, as the teacher moves over to the far right third of the board which is so far empty.
92	Wikorera aha *(Do it here)* ………. ….. (15)		He touches the board with his right arm, and then takes a few steps back to stand at the right side of the room. Sara and her benchmate stand, and Sara moves over to the board. She looks over to the left of the board, then writes a large 'F', then rubs it out and glances over at the teacher.
93	Ehh ntabwo wibuka se uburyo bazikora table? ….. *(You don't remember how to do the frequency table?)*		Teacher stands at the side of the board, half facing the student and half facing the rest of the class.

94	Ntago uzibuka. Duhera kuri egisi (*You don't remember? They start with x)*		
95		Ex. Ex …	A few students repeat 'X'. Sara writes 'x' on the board, beginning the table again.
96	Tugakurikiza honiki mumubwire.		
97		Yes. yes.	A few students respond. Sara draws the columns for a table.
98	Twakurikiza ho iki? Si biriya se? *(then followed by what?)*		
99	……….	/unclear/	Several students answer. Sara labels the columns F and F1, then draws a horizontal line to separate the headings from the table.
100	Si biriya se? *(Is it not like that?)*		The teacher looks up at the class
101		yes	A single student answers. The teacher remains at the right side of the room, looking through the coursebook. Sara continues to complete the table. She writes the numbers from 1-10 in the first column which she extends to make room. Most of the class are watching her work and copying the table into their notebooks. Sara takes a step back, and looks over at the table on the far left of the board, and begins to add the figures in the second column. She writes the first two figures, stops and looks at he table, writes

			three figures more, stops and looks, writes two more, stops, looks, and writes the remaining three figures. Then she raises he chalk to begin the third column. The teacher shifts his gaze between Sara and the class.
102 20:57- 21:05	Ariko ko mutamukurikira? mumubwire ibyo yandika hinaha *(Why are not following her? Tell her what to write)*		The teacher looks at the students seated on the right of the room. He gestures with his hand, arm half extended, to Sara.
103	………	Andika cumin a rimwe ….. (*Write eleven)*	Several students repeat
104	Kangahe? …		Teacher looks up and over the class and then back to the student working a the board.
105	………	/unclear/	Several students answer but nothing is distinct. Teacher remains standing to the far right of the room.
106	Ufite machine reo ni aze abe hafi ateranye. *(Someone with a calculator please come close to do the sum.)* ……….		Teacher turns to the class as he begins to speak, then back to the student working at the board. The student continues to complete the figures in the third column of the table. Other students are calling out, although what they say is unclear. At one point the teacher moves towards the board, looking at what the student is writing, then he steps back.

	………. (20 seconds)		
107	Ese ko mudafata machine? /… machine? …../ (*Why are you not using a calculator?)*	Nta machine dufite. *(We don't have calculator)/unclear/*	Teacher turns to the face the students seated on the right side of the room as he speaks. He gestures in the air with his right arm. Several students call out in response much of what they say is unclear.
108	Ya machine irihe? ... Cyangwa iyi ntago ikora? ……. (*Where is the calculator? Or it is not working.)*		Teacher crosses the room, to a desk at the back left. He picks up a calculator. The students and desk are out of view. He walks forward into the middle of the room.
109	Ninde urajya aduteranyiriza? *(Who is going to add?)*		The teacher holds the calculator up in the air in his right arm as he talks, he is facing away from the board.
110	………… (12)	Yes. Yego. Teacher.	Several students respond by calling out. Some raise their hands. Much of what they say is unclear. The teacher walks to the left and then back to the right of the room, with the calculator in his extended right arm.

111	Ariko ugire vuba. *(Do quickly*) ….. Quickly!		He passes the calculator to a student seated at the back right of the room (off camera). He turns towards the board and walks towards the board.
112	… quickly		He speaks as he walks towards the front right of the room.
113	…Sss!….. Stop making noise… watching the board! …..		He turns and looks up at the right side of the class. He gestures towards the board.
114	Mukurikire.mugenzi wanyu. *(Please follow you colleague)*		He looks at the student working at the board, and gestures towards her, and then out towards the class.
115	Teranya ibi byo hino umbwire ibyo ubona. Uhagare hino utadukingiriza…………. (15seconds) *(Sum up all of these. Stand here so that people can see.)*		He walks towards the student working at the board. He gestures towards the figures on the board, and the right side of the board. Then steps back to stand at the right of the room, looking through the coursebook.
116	Wabiteranyije byose? (Have you summed up all?)		Teacher looks towards the student at the board as he talks.
117		Iii (yes)	The student with the calculator answers immediately, in a loud voice

118	Rata buretse. Kora .. kora urebe ko murahuza. (*Wait. Sum up to see if you get the same answer.)*…………….. (17 seconds)		The teacher faces the student at the board and gestures towards her as he talks. The student at the board continues writing, looking between the two tables of figures that she has drawn.
119	abiri makumyabiri na rimwe ugabanye mirongo itanu (Take two hundred forty and divide by forty)		Teacher faces the student at the board as he talks. Other students are calling out, but much of what they say is unclear.
120		Kane ntabwo igaragara. *(Four is not clear)*	Several students respond
121	Ehh? ..		Teacher walks towards the board
122	singibi hano se ? korera hano….*(They are here. Do it here.)*		He gestures towards the formula in the middle section of the board. The student at the board follows and begins to work there. The teacher stands at the left of the board, facing the student working there, and half facing the class.
123	Ubwo ni magana abiri makumyabiri na rimwe?		

	…Turagabanya kangahe? …Ngo ni kangahe abonye? Kaane? *(It is two hundred twenty one. We divide by what? What do you get? Four)*		
124	……………….. (20 seconds)	N,ibice mirongo ine na bibiri.point forty two *(point forty two)*	The teacher remains standing at the left side of the room, while the student volunteer finishes the calculation. He hands the teacher the chalk which he takes, and goes back to her seat.
125	None se ubu baratsinze murabona badafite ane ku icumi? *(Did they pass? They haven't even got four out of ten)…*adequate		The teacher moves to the calculation, holding the chalk, and talking. He makes a mark on the board, as he says 'adequate' and looks up and smiles. A few students giggle. The teacher walks towards the left of the board.
126	Baratsinze?		The teacher looks up

127		ya	One student answers
128	Iii? … Bameze nka mwe… Aba bantu ni abaswa *(They have passed? They are like you.)*		The teacher stands to the left of the board, looking in his coursebook. He looks up and smiles.
129	……..	Baratsinze ehee oyaa (They passed. no)	Several students call out answers. Several students laugh,
130	Eh? .. Reka noneho tujye kuri frekenci…(*Let's now look at the frequency.)*		The teacher steps towards the board..
131	…. Cumulative frequency.		He raises his chalk to write on the far/right third
132	Abafite ikibazo mubaze. Any questions? (*Those who have a question, please ask)*		

133		Yes. yes question	A single student calls out clearly.
134	Ihhh? Ibi sinabisiba hari ikibazo?(*Can I clean these?)*		The teacher continues working on the far-right part of the board.
135		Oya. Bisibe (No clean)	
136	Simubizi se? Ibi ntawe utabizi. *(Do you know these? Everybody knows these.*		Teacher stoops down and picks up the cloth for wiping the board from the floor. He turns to face the class.
137	…………… (15)	/Oya teacher hoya. Bisibe turabizi. *(No teacher*	The teacher faces the class, cloth in hand. Several students answer. The teacher moves to clean the board and the answers get louder. The teacher makes a deliberate sweep and cleans the table from the board that the student volunteer had written.

		Clean them we know them.)/	
138	Mubirebe mu makaye yanyu birimo. (*Check it from your notebook they are there)*		He writes a new heading on the board, as he talks. '8.5.7 cumulative frequency diagram' Students are writing in their notebooks, flicking through their books looking at the board and talking quietly.
139	Ni frekenci .. the cumulative frequency the frequency what happen iba ukoze totali y'izi frekenci. Sibyo? One who can calculate y sibyo? Frequency polygon. Ubanza ukandika totali sibyo? Frequency ibanza noneho ugateranya ho n'uyu w'aha. Sibyo? Turagira kangahe? ..		Teacher finishes writing on the board (see figure 1). He underlines the headings on the chart with a long chalk stroke, then turns to the class and begins to talk. As he talks he points to and between the numbers in the second column of the table on the board. Each time the teacher says 'sibyo' and after the final two questions, he pauses, and turns towards the seated students. There is no clear change in students' behaviour from before teacher started talking. Still some are writing, some are looking at the board and the teacher but others aren't. Three students seated together are tussling with a coursebook between them, they make no visible sign of hearing the teacher start to talk.

	Niduteranya n'iyi turagira kangahe? *(The cumulative frequency is the frequency you get after summing up. isn't it? You start by writing the number which is here. isn't it? Then you add the number which is here. isn't it? What do we get? If we add this, what do we get?)*		
140	Ihh?		Teacher turns to face the seated students. He writes the first three numbers in the far-right hand column.
141		*/unclear/*	There is an inaudible response from students seated front left.
142	Ngaho nimuze mukomeze. *(Come and do it.)*		Teacher faces and addresses whole class. He holds the chalk in his right hand, which is raised to his head height and extended to the class.
143	Ufata uyu uraha ugateranya uyu uraha. Sibyo?		As he talks the teacher signals between the numbers he is referring to with his chalk.

	(You take the number which is here and you add the one which is here. isn't it?)		
144		*Ehhh! Yeees!*	At least two students give an audible response
145	Come …..		Teacher signals a student seated at the back right of the room with the chalk.
	Sibyo? *(isn't it)*		Teacher turns and addresses the seated students. The nominated students stands and comes from the back of the room. He takes the chalk and stands in front of the board. Teacher moves to the far side of the board. He looks at what the student at the board is writing. The student at the board also looks towards the teacher as he writes a few times. Student with the chalk writes the first answer in the right hand column, then turns to the teacher
146	Ugend auteranya uteranyaa Sibyo? *(You keep adding progressively. Isn't it?)*		Teacher turns to the student at the board and talks quietly, although it is still audible as the teacher is standing some distance away.
147	Itatu na kane uteranyije ho cumin a gatatu ni kangahe sha? (*Thirty four plus thirteen is equal to?)*		Teacher addresses the student at the board.

148	Itatu na kane plus MUMUBWIRE *(Thirty four plus, PLEASE TELL ME)*		The turn begins quietly, the last word is significantly louder, and the teacher turns to the class
149	Itatu na kane guteranya ho cumin a gatatu ni kangahe? (*Thirty four plus thirteen is equal to?)*		Teacher faces and addresses the class
150	………………..	*Ine na karindwi (Forty seven)*	Several students answer. The teacher stands on the right side of the class. He is holding the student book open in front of him but keeps his gaze on what the student at the board is writing.
151	None se si nkuko wafata summation ya frequence? Sibyo? *(It is like taking the sum of all frequencies. Isn't it?)*		As soon as the boy is finished, teacher moves to the front to stand next to him. Teacher takes the chalk from the boy without looking at him. The teacher half turns to the class. He indicates the middle column of the table, and indicates down the column with the chalk as he talks.

Appendix E Coursebook pages: Frequency polygon

(c) What speed would the car gain from rest in: (i) 8 s, (ii) 14 s?

8. Table 8.45 shows data from students who participated in blood transfusion at Maera Secondary School in a particular year.

	Month 1	Month 2	Month 3	Month 4
Boys	4	8	9	10
Girls	6	5	11	12

Table 8.45

(a) What type of graph would you draw using this data?

(b) Draw the graph for the data.

(c) Use the graph to determine.

(i) The least number of students who participated in the blood transfusion.

(ii) The largest number of students who participated in the blood transfusion.

(iii) The mean number of students who participated in the blood transfusion.

8.5.6 Histogram and frequency polygon

Activity 8.24

Work in groups.

From a mathematics dictionary, find the meaning of the terms histogram and frequency polygon.

Search from the internet the meaning of the two terms and compare your findings.

Can you think of any other source where you might find this information?

Distinguish between a histogram and a bar graph.

Learning point

A **histogram** is a diagram used to represent frequency distribution in an ungrouped data. A histogram resembles a bar graph or bar chart with the bars touching one another.

A **frequency polygon** is a line graph drawn by joining all the midpoints of the top of the bars of a histogram.

Example 8.16

Table 8.46 – shows how a group of 50 students preformed in a maths quiz marked out of ten.

Mark	1	2	3	4	5	6	7	8	9	10
f	2	2	11	11	12	7	4	1	0	0

Table 8.46

(a) *Using a suitable scale, say vertical scale 2cm: 4 units and horizontal scale. 1cm:1unit, represent this information on a histogram.*

(b) *On the same graph, draw a frequency polygon.*

Solution

Since this set represents discrete elements which are ungrouped, all the rectangles will be of the same width, and the frequencies will be represented by the heights of the rectangles.

Figure 8.15 shows the histogram and the frequency polygon for the frequency distribution in Table 8.46.

221

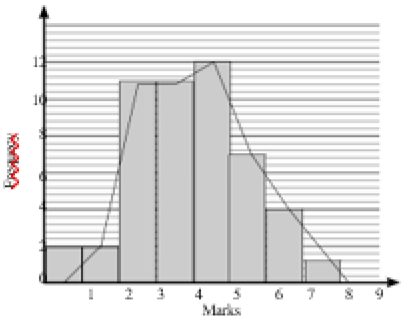


Fig. 8.15

Learning point

The graph obtained by joining the midpoints of the top of the consecutive bars is called a frequency polygon.

To complete the polygon, join the midpoint of the first bar to the bottom left hand corner of the bar and the midpoints of the last bar to the bottom right hand corner of that bar.

Example 8.17

The masses of a group of students are measured to the nearest kilogram and masses recorded as in table 8.47 below

Mass (kg)	*57*	*58*	*59*	*60*	*61*	*62*	*63*	*64*	*65*	*66*	*67*
Frequency	*20*	*36*	*44*	*46*	*39*	*30*	*22*	*17*	*16*	*4*	*2*

Table 8.47

(a) Construct a histogram to represent the data.

(b) Use your graph to estimate the mode.

(c) State the range of the distribution.

(d) Draw the frequency polygon represented by the histograph.

Solution

Using a scale vertical scale 2cm: 10 students Horizontal scale 2cm: 10

(a) Fig. 8.16 shows the required histogram.

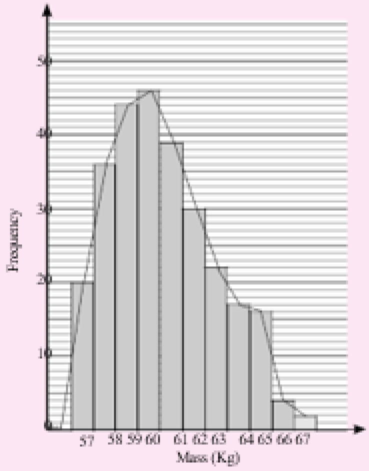


Fig. 8.16

(b) To estimate the mode graphically, we identify the bar that represents the highest frequency.

The mass with the highest frequency is 60 kg. It represents the mode.

(c) The highest mass = 67 kg

The lowest mass = 57 kg

∴ The range = 10 kg

(d) The graph joining the midpoints of top of the bars is the ***frequency polygon****. i.e Fig. (See fig 8.16 above)*

Example 8.18

The following histogram (fig. 8.17) shows the monthly wages (in FRW) of workers in a certain factory.

Appendix F Transcript: Surface area of cuboids

The teacher is wearing a white coat, which he and other (also non-maths and science) teachers sometimes wear at school. The teacher has two teaching materials with him, in addition to the coursebook: a large-sized yellow plastic set square and a 3-dimensional model of a cuboid. He sets these down on a desk to the front right of the room, soon after he enters. The lesson begins as usual. The teacher draws two vertical lines on the blackboard, dividing it into three roughly equal-sized sections. He writes 'MATH' in capital letters in the far top-left corner, and the day's date below it. Then he begins to copy a section of text from the coursebook onto the left-hand column of the board (the text is given in the textbox below). The students remain seated and talk among themselves. Most look intermittently at the board and begin to copy the text and diagram into their notebooks. The volume of student talk is fairly loud in relation to other lessons. Accordingly, at one point the teacher turns to the students and says:

'Keep silent! Ssss! Eh!'

<u>Unit 7 solids</u> <u>definition</u> is a dimension figure that has a flat surface for each face   <u>2.1 Cuboid</u> definition a solid bounded by three pairs of identical face which are rectangle

(3D diagram of a cuboid, labelled 'face')

Figure 1 teacher board work at start of episode

After 2 minutes of writing on the board, the teacher takes a step back, examines what he has written. He then turns to face the students, signalling that the lesson has started.

Line/time	Teacher	Student	Observations
1.			The teacher writes text from the coursebook onto the board. Some students turn to each other and talk together. Others look around the room. Some students copy what the teacher is writing. The teacher adds the label 'face' to the diagram, linking the word to the top of the cuboid diagram with a line.
2.	*Ssss..eh…keep silent….*		The teacher finishes drawing the diagram of the cuboid. He steps to the left of the board and faces the class as he says quietly: The majority of students turn to look at the teacher.
3.	EH....This is a shape of a cuboid.		He walks to the front right of the room where he picks ups the cuboid model and the yellow set square. He moves to stand in the

			front of the middle of the blackboard. He turns to the right of the room and turns the model cuboid in his extended right hand as he begins to talk.
4.	..	yes	All of the students visible on camera at the right of the room, which the teacher faces, are watching the teacher as he talks. Students seated on the left are mainly writing or looking at the board (see photo 3). A single student speaks just audibly
5.	This is called the face. This is called Muriyi nguni aha niho twita .. vertext …. (*In this angle we call it vertex)* Kuri iyi migongo niho twita edge .. (*On these, we call them)* Murumva? (*Are you listening)* …		As he talks, the teacher turns and moves towards the diagram on the left side of the board. He switches the set square and cuboid into his left hand and picks up a piece of chalk with his right. All students on camera look towards the front and/or write in their notebooks. (photo 4) He labels the diagram (vertex, edge) as he talks. As he stops labelling he says 'murumva' quietly, and turns to face the students seated on the left of the room. He transfers the cuboid back to his right hand, and hooks the set square over his wrist.
6.	Ku migongo. (*On the lines)* ra kibuye for this cuboid? *(how many face?)* how many face?		He raises the cuboid and touches the top edge of the model. Teacher turns to the middle of the room, and walks through the centre towards the students seated at the right of the room still

			holding the cuboid high in his hand. As he says 'how many face' he fully extends his right arm and dangles the model cuboid above the heads of the students seated along the front row. One student, seated middle right, points with his index finger, arm extended, towards the model and begins to 'count off' the number of sides. Other students look at the model, or the diagram on the board. Students seated on the left of the room are looking at each other. (photo 5)
7.	……..	Six. Six. Eight. six. eight.	Several students seated on the right of the room answer. Students on the left look at each other and at the board but don't seem to be answering.
8.	Every face has?		Teacher still standing on the right side of the room and holding the cuboid model in the air. The students seated there are watching the teacher and/or the model and providing answers. The students on the other side of the room are talking together (photo 6)

9.	…	six. Six. Eight. /Eight /	Student responses become louder. The teacher puts the cuboid model down on a desk on the front right, near the back of the room.
10.	/Is a/ rectangle.		The teacher turns his back on students and walks towards the front left of the room. He seems to read the text he has written on the board, and reads aloud ‘is a rectangle’
11.	…	six. Eight. Six *(unclear)*	Students keep answering as the teacher moves towards the board
12.	Sibyo? *(Isn’t it?)* …..		The teacher says this as he walks towards the diagram on the board.
13.	Is a rectangle.		He stops by the front left desk, turns to the middle of the room and says ‘
14.		Six …..	One student says loudly. As he says this the teacher picks up his copy of the coursebook from the front left desk. Teacher is at the front left of the room consulting the book. Many students are talking together.
15.	sss! Sss! HOW MANY FACE?		Teacher speaks loudly looking towards the students seated at the right of the room. He moves from the front left to the front right

			of the room still holding the coursebook, gesturing with his hand towards the seated students. (photo 7) the teacher bids to get students attention.
16.	…	six. teacher six. Eight. Six. Six face.	Several students answer quite loudly. As students answer the teacher moves to the desk on the front right of the room and picks up the cuboid model, which has been passed between students up to there.
17.	Face. /surface. In a rectangle. Eh! /	/six. teacher six. Eight. Six. Six /	The students on the right side look at the teacher and the model again (photo 8) Students continue to answer as the teacher talks. He lifts the model in the air, still facing the students seated on the right. As he says ‘eh’ he puts the model back down on the desk, and turns still holding the book, back towards the board.
18.			Teacher moves back to the front left, and writes on the board to the bottom right of the diagram of the cuboid ‘6 faces’. (photo 9) Student attention follows him, and some write as he writes
19.	………………………………. (30 seconds)	*Six face. Ni umunani, numunani (There*	He looks in the coursebook, and writes and then underlines the following heading, still working in the first third of the board

		are eight, eight) *Ni cumi nine* *(There are fourteen)* */unclear/*	‘<u>7.2 surface area of cuboid’</u> Students continue to talk between themselves, but quietly as if supporting the teacher in his next ‘preparation’ Some look at the board and write (photo 10) . The recorded talk is mathematical.
20.	We are going to see how to find		The teacher walks into the front right of the room, still holding the coursebook in his hand. He picks up a piece of chalk from a desk at the front right as he starts talking. He looks up at the students seated on the right. (photo 11)
21.	how to find the ..surface ..area of cuboid		His voice increases in volume as he straightens up, turns and walks towards the board
22.	… you see? ..This is called the? .. length Sibyo? *(isn’t it?)*		He re-draws a line of the diagram in the pause. As he says ‘length’ and ‘width’ he labels the diagram.
23.		yes	A single student answers the teacher in the two second pause the teacher leaves
24.	This is called the ..width. Sibyo? *(isn’t it?)* …		

25.		yes	Again, a single student answers in the short pause left by the teacher, in a voice that is audible to the class. Other students are talking to each other quietly, and some are turned to each other.
26.	sss! This is called ….		Teacher writes the label 'height' then looks up.
27.	are you looking here?		Some students turn to face the board.
28.	…. are you .. looking for this figure?		He looks up and around the room. Students either face the board or write in their notebooks (photo 13)
29.		Yes … yes…	A single student answers loudly
30.	Follow …		The teacher walks towards the right of the room. He speaks in a low tone, his gaze moves around students seated on the right as he walks. students either look at the board or write in their notebooks. (photo 14)
31.		Yes …	
32.	For a cuboid has?		The teacher walks towards a desk. The student hands him the cuboid (photo 15)

33.	has six face every two face are equal … and are rectangle.		Photo 16. The teacher holds the cuboid and touches the sides of the model as he talks.
34.		*yes*	
35.	Are you looking?		
36.		*yes*	
37.	You see you know to calculate the the surface area of triangle .. sibyo? … SIMUBIZI? *(Isn't it? Don't you know?)*		Teacher middle right, holding the model cuboid, facing the students on the right side of the room. Photo 17.
38.		Gukarikireiting *(To calculate)* the area surface	This is very quiet.
39.	Of a triangle. .. of of a rectangle. SIBYO? (isn't it?)… Length times width		Teacher middle right, holding the model cuboid, facing the middle of the room. Photo 18
40.		eeeh, yes	A single student, quite loudly
41.	Sibyo *(isn't it?)*		Teacher middle right, holding the model cuboid, facing the middle of the room.
42.		Yes	Several students answer quite loudly

43.	Sikobigenda? (Isn't it?)		
44.		Yego (yes)	Several students answer quite loudly. This is 'performance of success.
45.	Ubwo ubuso dufite face zingahe? (*The area How many sides?)*		Teacher is still standing at the middle right side of the room, facing and talking to students on the right. Photo 19
46.	Esh/eshstu/ (six)	/Six./ Hatsheput *(Six)*	As the teacher answer his own question 'esheshstu', students echo 'six'. Then, several students respond.
47.	Kubera dufite two face zigiye zingana ebyiri ebyiri. Turashaka ubuso bwa face eshatu zitandukanye. Sibyo? Noneho kuri buri face tugende dukuba kabiri. *(Because we have two equal sides. We find the surface area of three different sides. Isn't it? Then we multiply by two for each surface area. Isn't it?)*		Teacher holds and points to the model as he talks, standing over the students seated in the right of the room. Students at the right are looking, and students who can be seen on the left as well.
48.	…	Kabiri *(Two times)*	A single student repeats the teacher's last word
49.	Sibyo? *(isn't it)*		Teacher hands the cuboid back to seated students. He turns and moves back towards the board and begins to write under the heading at the bottom of the far left third. Students begin to pass

			around the cuboid again. Most students turn to the board and begin to copy what the teacher is writing into their notebooks.
50.	………. ………. ……….	Six. eight. eh!	The teacher is writing on the board. Photo 22 Under the heading that he wrote in line 16 '<u>7.2 surface area of cuboid'</u> He writes: 'The surface area of a cuboid of length (l), width (w) and height (h)' There is no more space on the left section of the board, and the teacher continues to write on the top of the middle section 'are given by`' The volume of student chatter rises. Most is unclear, although some students are still giving answers. Most students appear to be copying what the teacher is writing in their books.

51.	Are given by ….. surface area equals ………………..Sibyo? *(Isn't it?)*		The teacher is writing the text and speaks it aloud as he writes. His back is to the class, but his voice is audible. Photo 22. 'are given by SA As T writes 'SA' he says 'surface area'. He writes 'SA – 2 LW + 2LH + 2WH' Photo 23. and then draws a circle around the formula. Then he steps away from the board, turns to face the class and says 'sibyo'.
52.	Izi ni face ebyiri ebyiri zigiye zingana. Murebe hano looking here.. Sibyo? … Length …. length times … width *(These are two equal sides. Look at here.)*		The teacher moves to stand in front of the diagram of a cuboid in the far-left column of the board. He points at the diagram with his chalk as he talks. Most students look towards him. He is showing students the formula in relation to the diagram ('any cuboid') on the board
53.	Murabireba? Iyi ni rectangle imwe. Sibyo? turakuba kabiri ubuso bwiyi rectangle. Turakuba kabiri. Sibyo?		As he talks the teacher points to the labels and aspects of the diagram that he is referring to.

	(Do you see how? This is one rectangle. Isn't it? We multiply by two the area of this rectangle. Isn't it?)		
54.		Yess!	One student answers loudly
55.	Niyo yiyi. Sibyo? Iyi yo hasi, twongere duteranyeho ... length … times height … *(This rectangle is the same as this. Isn't it? The one below, then we add.)*		As he says 'Niyo yiyi' *(this one)* he moves over to the formula, and then back to the diagram as he says 'Iyo yo hasi' *(is the same as this one)* he is drawn on the board. The teacher points to his diagram, and the parts that show length and height as he says these words. Photo 24
56.	Ni iki gihande iki. Iyi face niriya yindi. Si ebyiri? Sibyo? Muri kubireba? *(Even this side. This side and that one. Isn't it? Do see how?)*		The teacher remains standing to the left of the board by the diagram, and indicating the diagram as he talks. As the teacher says 'are you looking for this' he moves to the desks in the middle right of the room and picks up the cuboid model.
57.		yes	A single student answers

58.	Twongere duteranyehol .. width times height .. mpande zo ku, izingizi ziteganye nazo zirebana.. Are you looking for this? …. *(We add again These sides too. We add the surface area of opposite sides)*		The teacher remains standing to the left of the board by the diagram, and indicating the diagram as he talks. Most students are looking photo 25 As he says 'are you looking for this, he walks over to the right of the room and picks up the cuboid.
59.		yes	A single student answers quietly.
60.	Izi ebyiri. Izi ebyiri sibyo? .. nizi ebyiri, sibyo? Ntizibaye eshatu ubwo? Esheshatu. / *(These two. These two, isn't it? These two also. Are there now six? Six.)*		He uses the cuboid to show the sides he is talking about. Again, he is framing and answering his own questions. Students role is to agree. (photo 26)
61.	…	Yes. Eh. Esheshatu. *(six)*	A few students answer.
62.	ehh esheshatu. Ebyiri ebyiri zingana….Simubireba? *(Six, two by two. Two equal sides. Do you see how?)*		He pats the two sides he refers to together as he talks. As the teacher says 'simubireba? (do you see how?), he turns back to the board.

63.	..	Yes!	A single student loudly. Teacher walks back to the middle of the board. He writes on the board as he continues to address the class in a loud voice.
64.	what is the unit of area? … eh? … unit of surface area …heh? is..? meters square. Sibyo? (isn't it?) Or ..centimetre square or kilometre square unit of / meter, side, square /unclear/ Sibyo? *(Isn't it?)*)	/unclear/	The teacher asks the first question, chalk held high and poised to write, half facing the class. He turns towards the class further, as he says 'eh?' Several students respond but what they say is unclear. The teacher continues to prompt the class to give him the answer. As he writes 'unit of surface area', he says it, and makes it a question for students by saying 'eh?' Several students respond but what they say is unclear. Photo 27 He answers his own question as he completes the sentence on the board 'unit of area is M2 or CM2 or KM2'

			As he finishes writing he says 'sibyo' and moves to the front left of the room and picks up the coursebook. Students cooperate by sitting quietly. Some write. Others look across the room or chat quietly.
65.	(48 second pause)		Teacher stands facing the middle section of the board, reading the coursebook which he holds in front of him before he starts to write. Students cooperate by sitting quietly. Some write. Others look across the room or chat quietly. Photo 28
66.	(1 minute and 47 seconds of writing)		He writes text from the coursebook holding the book in his left hand (photo 29). Students cooperate by sitting quietly. Some write. Others look across the room or chat quietly. Text: 'Example the net of a cuboid consists of a series of rectangles. How many rectangles are there? What is the surface area of the cuboid if it measure 6cm by 3 cm by 2 cm?

			Solution' He underlines the word solution in a single stroke, and moves towards the desk at the front left.
67.	Who can come to correct this question? Anyone who can come to correct the answer …Hari uwaza ngo agerageze? (*Who can try)* ….. heh? ….		He puts down the coursebook and picks up the set square and holds it aloft. He points to the example on the board as he says 'this question', then turns to look and gesture out at the class (photo 30). He moves to the left of the room, and looks over students there as he continues. The pauses he leaves and different ways of appealing for volunteers show this is a genuine move to nominate a volunteer. Students continue writing, chatting quietly or looking across the room.
68.	Let me try to calculate to draw the figure ………. ………. ………. ……….		Teacher turns to the middle section of the board and begins to draw the cuboid. Students continue to talk quietly. Three students on the front right can see and are copying what the teacher draws. Others can't see because his body is blocking the drawing. Most students turn face each other and talk together. The

	………. ………. ………. ………. ………. ………. ………. ………. ………. ………. (140 seconds)		students with the model cuboid continue to pass it between them and seem to be talking about it. Photo 31. Two students get up and change places, taking their pens and notebooks with them.
69.	Ntawaza ngo agerageze?*(Who can come and try)* .. who can come to find the surface area? … can you try?		Teacher finishes labelling the diagram and steps back to the left side of the classroom, talking as he moves away from the diagram. He looks at the diagram, then out at the class. His first utterance is fast. The second is more deliberate. He faces the students as he talks. One student raises his hand and clicks his fingers.
70.	…	eh teacher	The teacher looks around the classroom. In the three second pause that he leaves the student who has his hand up calls out:

71.	Sibyo …*(Isn't it?)*		The teacher moves his gaze around the room.
72.		teacher. teacher	The student with his hand up calls again for the teacher's attention:
73.	How many rectangles are there?		The teacher points to the diagram of the cuboid in the middle of the board. He speaks loudly. Most students are facing the teacher at this point.
74.	…….	Four. Four. Two. Four. Six. /Six/	Several students call out. Most students are looking at the teacher. The volunteer on the left still has his hand raised (
75.	/Six/ rectangle. Sibyo? *(Isn't it?)*		
76.		four	A single student calls out:
77.	Iyi niyi, niyi niyi, niyi niyi yo hasi. Is six. Sibyo? *(This side and that, this side and that, and this side and the one below. Isn't it?)*		The teacher turns to the second diagram of the cuboid, that he has drawn in the middle of the blackboard. He counts off the sides with his chalk as he talks. Most students are watching

78.	…	yes	The teacher looks up and pauses for three seconds. A single student calls out loudly.
79.	Sibyo? *(Isn't it?)*		
80.		yes	A single student
81.	Sibyo? *(Isn't it?)* Urabanza ushake surface area of rectangle one. Sibyo? Sibyo. Rectangle one and surface area of rectangle two. …Siko bimeze? Surface area of rectangle three. *(Isn't it? You start by finding ...Isn't it?)* Noneho ugende ukuba kabiri ukuba kabiri *(Then you multiply by two)* Sibyo? …Siko bimeze?... (Isn't it?)		The teacher writes the process of calculation on the board as he talks. He writes 'S.A. (R.1)' As he says: 'Sibyo? Urabanza ushake surface area of rectangle one. Sibyo? Then he writes 'S.A (R2)' as he says:

			'Sibyo. Rectangle one and surface area of rectangle two. …Siko bimeze? Surface area of rectangle three. *(Isn't it? You start by finding ...Isn't it?)* Noneho ugende ukuba kabiri ukuba kabiri (*Then you multiply by two)* Sibyo? …Siko bimeze?... Photo 36
82.	…	yes	The teacher finishes writing the formula, adding: S.A. (R.3).
83.	Come		The teacher turns away from the board towards the class as he asks again for a volunteer. He turns a full circle, standing in the middle of the room, looking for a volunteer.
84.	……	/unclear many students talking at once/	Volume of student talk rises. Photo 37
85.	Ntabwo muri kubibona? *(You don't it?)*		Teacher turns back to the board as he says
86.		/unclear/	Several students respond. what they say is unclear.

87.	Rectangle ya mbere ngizi, zirimo ari face ebyiri. Sibyo? *(The first rectangle is here. There are two faces)* this is length .. sibyo? *(Isn't it?)* Length, width, height sibyo? *(Isn't it?)*…..		The teacher returns to stand in front of his diagram in the middle of the board. He faces the class, and indicates the diagram he has drawn with his left arm. The teacher shows the measurement label on his diagram 'this is length', he then adds the labels '(l), (w), (h)' to the diagram as he talks.
88.		yes	One student answers quietly
89.	Wenda reka dukube kabiri. Sibyo? *(Let's us multiply by two. Isn't it?)* Length and width, sibyo. *(Isn't it?)*		The teacher begins to write the calculation for the first rectangle. He writes '2 (LxW)='
90.		yes	
91.	Ni kangahe? *(How much?)*		Teacher looks up at the class photo 39
92.	……	/ student responses unclear	Teacher writes

		but several answering/	'2 (6cm x 3cm)'
93.	Dukubye? *(We multiply by)*		The teacher turns to face the class
94.		Kabiri *(Two times)* Ni cumi nagatatu, cumi na *(It is fifteen.)*	Several students answer. student engagement is higher in this exchange than previous presentation exchanges. This seems more genuinely collaborative.
95.	Sibyo? …Turagira kangahe? dukubye kabiri ni kangahe? …heh? *(Isn't it? What do we get? Eighteen multiply by two, we get)*	/unclear/	Teacher writes on the board, several students answer but their voices are unclear. it seems that the teacher hears at least one student answer '18', then the teacher asks the class to 'dukubye kabiri ni kangahe? '
96.	….	Itatu gatandatu (Thirty six)	A few students answer
97.	Centimeter square. Hagire uza akore *(Who can come and try)* ….. for rectangle two …..heeeh?		Teacher writes the following answer, as he says: 'centimetre square' '=36cm2'

			He moves to the left of the board, as he again asks for a volunteer. This time, several students volunteer and he selects someone. The volunteers include the students who volunteered in line 63 and 65, but the teacher selects a different student. This indicates that the teacher didn't want to select the 'strongest' students to demonstrate and/or wanted to see that other students were ready to try the task. Photo 40
98.	………… (12 seconds)	/ teacher.teacher/	The teacher looks around the room. At least three students, seated on different rows, raise their hands and click their fingers.
99.	For rectangle two.		Teacher hands a student seated on the left of the room the chalk, as he says: He nominates her.
100.	SI UGUKUBAHO KABIRI SE? udashaka gukuba kabiri washaka ubuso bwa face esheshatu. Sibyo ra? .. *(It's just to multiply by two. If you don't want to multiply by two, you calculate the surface area of six sides. Isn't it?)*		He moves to the students on the right of the room, from his position at the front left. His voice is quite loud and he gestures emphatically (photo 41).

101.		yes	One student answers
102.	Ariko ebyiri ebyiri ziba zingana gukuba kabiri biroroshye … *(But two surface area are equal that's why multiplying by two is simple)*		Teacher picks up the model cuboid from a desk and turns to face the student working at the board. Photo 42
103.	Niba ushatse ubuso bwaha kubera hangana naha urakuba kabiri *(If you find the surface area of this side, you then multiply by two because they are equal)*		He looks towards students seated on the left as he continues talking. he holds the model cuboid at chest height, and points to the faces of the model as he talks. Most students are looking at thee teacher. Photo 43
104.	Niba ushatse ubwahano, ntabwo ubireba se? ..*(If you calculate the area of this side, don't you know it?)*		The volunteer finishes and stands to the side. Teacher notice and turns to look, as he finishes what he is saying.
105.	Reka reka nubwiyi NIYI. Hano kugera aha. Hano nyine hangana 2 centermeter sibyo? Kubwizi mpande zihagaze *(Who can tell us the area of THIS side? Here is 2cm, isn't it? What about these vertical sides?)*		Teacher walks towards the board. He talks loudly. Photo 45. He pauses a moment as he reads what the student has written the moves closer. Most students are watching the teacher

			Teacher is both addressing the student at the board and the class. he is enabling her to continue the task -typical st demo.
106.	…..		She moves in and writes the answer he is asking for. He moves to the left. -typical st demo.
107.	NO! length times height	/	The teacher reads what the volunteer writes and loudly says 'no'. She stops and looks up (photo 48). Teacher steps further to the left.
108.		Height. hate. height Ariko subundi biriya nibiki? Njyewe rwose byanyobeye. *(What is that? I am confused.)*	Students repeat the word height with different pronunciations. Like the teacher says it 'hate', and height.
109.	Ntubireba se? *(Don't you see that?)*		He gestures towards the student at the board

110.	Ni ubuhagarike. Hari uburebure, ubuhagarike nubutambike. Subireba hano se? do ubu ni uburebure, ubutambike ni ubu. Ubu ni ubuhagarike (6) *(This is the height. This is the length, the height and the length. Don't you see? This is the length and this is the width. This is the height.)*		The teacher stands near students seated on the back-right rows. He gestures emphatically as he talks, and shows with the model cuboid what he is saying. Photo 48
111.	……….. (12)	Teacher byagucanga nawe ari ubwa mbere ubibonye ibi bintu rwose (*Teacher you are confused. It seems like, it is the first time you see these things)*	Several students talk in this pause left by the teacher. the teacher looks at the students., his posture open and listens. He looks over at the student at the board,. Other students giggle – this is a power play, but legitimate, as the teacher is mixing up the words for triangle and rectangle Photo 49
112.	Nukuvuga ngo iba igizwe na triangle esheshatu. Kandi ubuso bwa triangle ni uburebure gukuba. Si uruhande rumwe gukuba urundi se? Mubimenye.		Teacher stands at the back right and addresses students there emphatically Photo 50

	(That means, it has three triangles. And the area of triangle is the length times. Isn't one side times the other? Remember that.)		
113.	…………….. (16 seconds)	Ibyo bintu nibiki? Ntabwo bibaho. *(What are those things? They don't exist.)*	Student being smart – this is against the idea of 'we' solving the problem together The teacher turns to face the board as the student finishes the calculation.
114.	*Yes.*		The student at the board looks up and the teacher answers 'yes' Photo 51. Yes – feedback to girl at board, at most no or yes. Sometimes neither.
115.	For triangle ya gatatu *(For the third triangle)*		
116.	(15)	Eh teacher.	Girl goes back to seat. Other students are volunteering with hands up and clicking fingers. T signals one boy who climbs under his desk to come to the front and take the chalk-baton Photo 52

117.	Height times width …..		Volunteer crouches to complete the calculation at the bottom of the board. Teacher talks to him, loud enough for the class to hear. Teacher walks over to students at the right side.
118.	FOLLOW! Are you follow? …what happen? Ufite ikibazo ubaze. Sibyo? …Abaze turamusobanurira ariko ntasakurize abandi bana. *(Any question? Isn't it? If you have a question please ask but don't make noise)*		Teacher stands facing the students at the back right. He speaks loudly and raises his arm. Photo 53
119.	*Yes. Buretse, ba buretse. (Wait, wait a moment) …………… (15 seconds)*		The teacher looks at the student working at the board and walks towards him. It seems that a student wants to ask a question, and the teacher is asking them to wait so he can correct the boy at the board. Photo 54 Teacher stands watching the student working at the board. The teacher is trying to work out the students method.
120.	Ibyose kandi ukoze ubikuye he? *(Where do you get what you are doing?) …..*		Student has finished. Teacher asks him a genuine question! Photo 55

121.		/unclear/	Student at board replies and shows photo 56
122.	Ubanza ugakora ibiri muri blaket mo imbere. Ntubize amategeko yo gukora fraction? 2 dukubye 12 nako 6. Gatata cm square? *(You start with what is in the bracket. Have you not learnt the law of fractions? Two time 12 no 6. Is it 6cm squared?)*	(no. yes)	Teacher is talking, student at the board is talking and several other students are talking. Teacher talks him through the process. Student listens and writes it how the teacher says. Student at the board rubs out his work, then adds a new line. photo 57
123.	Are you follow? ………… (12 seconds)		Teacher walks to the left of the room. He watches as the student at the board finishes writing. The student finishes and looks up towards the teacher. Photo 58. The teacher doesn’t respond, The student turns back to look at his work on the board, then moves to his seat
124.	Abantu batari kubona aho turi kubikura ni hagire umanika..,Hands up. *(If you don’t how were are doing it, please hands up.)*		Teacher stands middle left. He looks over the class. He raises his hand. Student at board returns to seat.
125.		Abantu batari *(Two people)*	A student distinctly says

126.	SSS..Kumva aho turikubivana Hands up. (*How we are doing it)*		The teacher raises his hand as he talks
127.	…..	Teacher teacher …	He walks into the middle of the room, gesturing with his index finger extended, as if looking to select someone. A student at the front left raises their hand, along with two other students visible on camera. A different student calls for the teacher's attention verbally The teacher selects the student front left, with a gesture. Photo 60.
128.	…	/unclear/	The student he selected asks their question.
129.	Eh?		The teacher is walking towards the front as the student asks. He raises his arm, as he says 'eh?' indicating that he has not heard and he wants a repeat.
130.	S: Ikibazo. Waretse tukabikorera icyarimwe kugirango tubone uko tubikora neza. (*That's a problem. Why can't do all at the same time so that we do them properly)*Biriya biratujijisha tukabikorera icyarimwe nkuko formule ibitwereka, Eh!Eh! *(That method confuses us and we end doing all of them as the formula shows. Eh! Eh!)*		The student repeats the question louder

131.	Ukabikorera icyarimwe? *(Eh! Are you doing it altogether?)*		The teacher gestures towards the formula on the board as he asks the question. Photo 61.
132.		: iiih (yes) Yes eh. teacher! Teacher!	Several r students are raising their hands and calling out,
133.	Buretse turebe *(Wait a moment.)*		The teacher moves to the right of the board
134.	Ukabiteranyiriza hamwe? *(Are you adding them altogether?)*		The teacher stands by the board
135.	…	Yes. Yes. Yes.	At least three students answer
136.	Nabyo nta kibazo, Sibyo? Ubwo ni, ni total y izi surfaces zose tubonye, Sibyo? *(That's fine too. That's the total of all of these surface areas we got. Isn't it?)*		Teach continues writing the formula, he looks down to the example as he talks.
137.	……….. (12 seconds)	Eeeh……….	One student calls out.

		surface…. /unclear/	The teacher writes a formula on the board. ‘S.A = 36 cm2 + 24 cm2 + 12 cm2 =’ Other students talk to each other.
138.	Turagira kangahe? *(What do we get?)*		Photo 64 Teacher points to the formula he has written at the top of the board as he talks.
139.	…..	*/ unclear/*	Lots of responses, but nothing distinct. Teacher remains looking at the formula he has written
140.	Mumbwire, dufite kangahe? (*Tell me, what do we get?)*		Teacher remains looking at the formula he has written
141.	S: Ntago ndi kubyumva! Bon nyine,,, (*I don’t understand)* Mirongo itandatu na gatandatu uteranyije,, Mirongo irindwi na kabiri *(Sixty six plus seventy two)*		Several students talking here. They are not calling out or shouting, but talking calmly and audibly. At least two students talk. The teacher writes ’72 cm2’

142.	Eh! …..		The teacher looks towards the class
143.	Genda uyandike eh! ku kibaho turebe; Turebe ko twayikorera ubugororangingo. *(Eh! ….Go and write it. Eh! On the blackboard so that we can correct you)*		The teacher nods towards a student seated on the back right of the room and says: As he talks he moves towards the student and hands him the chalk. .
144.	………….(15)		The student comes to the front and writes his formula on the board. The teacher stands to the side. The class watch. The student writes: 'S.A. Lx2 + Hx2 +Wx2'.
145.	Eh, ni iriya mwize? (Eh! Is what you have learnt?)		Teacher looks over the class and gestures to the student's work on the board
146.		OYA *(NO)* REKA DA *(NO WAY)* OYA *(NO)* OYA *(NO)*	Several students answer loudly.
147.	Yandike iye, nawe urandika iyawe, Sibyo? *(Write yours and they write theirs. Isn't it?)*		The teacher points towards the students seated on the right of the room, and says:

148.	…..	Ngo nawe jya kwandika (Go and write yours.)	One student, seated nearby, says:
149.	Babu' buretse, iyi nayo nayibonye birangana *(Wait a moment; I can see that they are equal) …*		The teacher walks towards the board, gesturing towards the second formula. The student who wrote it gestures up towards it too.
150.	Birangana n ibi (It is equal to this)		The teacher takes the chalk from the student, who returns to his seat, then turns to the class and says: Several students call out
151.	Hagire uza yandike iye nawe (*Who can come and write theirs? Let her try.)*		As the student returns to his seat, the teacher points towards a student seated at the back right of the room, as he says:
152.	Come and write your formula		The student walks over to the teacher and takes the chalk from him. The teacher smiles broadly as he hands over the chalk, saying:
153.	….. (5 seconds)	The surface. the surface. eceka Ntago ari surface	The volunteer starts writing on the board. The teacher stands to the left side. Several students are talking loudly.

		Bari gushaka /surface/ *(It is not the surface they trying to find)*	They continue talking through the teacher's next turn.
154.	/Mumureke/ Mumureke ariko.. (Let him try. Let him try..)		Teacher turns to the student who has called out, and says:
155.	Nonese ko uri kureba ibyo twakoze? (Why are you looking at what we did?)		Teacher faces the student working at the board
156.		ehhh	The student at the board turns to look at the teacher, saying:
157.	Turi kukubaza formula uzi yandike …..*(We are asking you to write your formula.)*		Teacher continues addressing student at the board.
158.		Nagirengo upointed ya total	The student at the board responds to the teacher, asking him clearly while pointing to the text on the board. Photo 73

		surface cyangwa lateral surface? *(I want to point the total surface or lateral surface?)*	
159.		Ni lateral surface *(It is lateral surface)*	A student calls out
160.	Eh?		The teacher exclaims
161.		Ni lateral surface *(It is lateral surface)* Surface of base plus lateral surface ….	The seated student repeats his/her answer aloud. At least two other student chime in. As they talk, the student at the board adds figures to his formula. The he turns towards the teacher and opens his arms wide,
162.	………. (10)	Oya lateral surface /unclear/	The student volunteer returns to his seat. Some students call out to him. The student volunteer turns and goes back to the board.

			He rubs out and rewrites the last letter 'LS'. The student then walks to the teacher and hands him the chalk.
163.	How many surface of base?		As the teacher takes the chalk he says: He moves to stand centrally
164.	Dufite bases ebyiri.. sibyo? Sibyo? *(We have two bases.. isn't it? isn't it?)*		He raises the model cuboid and touches the side as he says:
165.	Sibyo.,Singizi? ….. Si izingizi? *(isn't it. Is it this? this?)*		Teacher moves back and begins to write on the board. He writes under the calculation that the last volunteer wrote.
166.	Noneho lateral surface .. Si ibihande, bine?... Si bine? (Now lateral surface .. not four sides? not four?)		Teacher steps to the side and turns to the class. He shows students the four long sides of the model cuboid as he talks.
167.	Nese urabona hari aho bitaniye n' ibi? *(Is there any difference between these sides?)* …		Teacher steps back to the equation on the board, as he talks
168.		Ahubwo Iyongiyo *(You can use that)*	A student answers

169.	eh?		Teacher is still writing on the board
170.		niyo yaba nziza (*That one is much better)*	Another student answers
171.	…………………. (22 seconds)	Ni iyo ni iyo *(That one. That one)* Iyo niyo wafata *(You can take that) /unclear/*	A student answers. Another student answers. Lots of students are commenting aloud as the teacher works on the board. Teacher writes his equation.
172.	Ahubwo iyi niyo yaba nziza (But this is one is better)		The teacher finishes writing, circling the formula he has written
173.	Ibi nibyo bya….Iyi niyo lateral surface.. Sibyo? Ikaba surface of base..*(That is….that is the lateral surface. Isn't it? This is the surface of the base.)*		Teacher points to the formula he has written as he talks. He is translating his method into the language of the students' method. Under the formula he has written, he writes the terms that the students are using (lateral surface and surface of base)
174.	si ibi se? Turi kubireba? *Isn't it? Do you see that?) …* byo mwize ntaho bitaniye n ibi,		T finishes writing his equation, and faces class again, holding the cuboid Photo 82.

	Sibyo? …Sibyo? *(There is no difference between these and what you learnt)*		
175.		Yes. Yes. Yes.	Three different students answer
176.	Formule ntago yakubera imbogamizi, ahubwo ikibazo ni uko wabona igisubizo. Sibyo? *(The problem is not the formula but how to find the answer. Isn't it?)*		Teacher walks over the right side of the room.
177.		/unclear/	
178.	/Form/ule uzi yose uzajye uyikoresha, sibyo? Ah, ikibazo… Igisubizo gihure ..sibyo? *(You can use any* *formula you know. A problem, the same answer. Isn't it?)*		He talks over a student. Teacher stands on the right of the room, talking to students there. Photo 83.

179.	..... (5 seconds)	N'igisubizo gihure *(It is the same answer.)* Icya mbere cyaducanze *(The first one is confusing)*	The teacher walks back to the board. Several students talking. At least two can be heard.
180.	Ariko… iyi formule iri very simplified..Niyo mpamv,,, Niyo naba conseilla gukoresha.. Sibyo? Urabona iyi itari simplified? Ni uko ari ubwa mbere muyibonye *(But …This formula is very simplified. That's why. I advise you to use it. Isn't it? Don't you see that this formula is simplified)*		Teacher stands at the board and points to the formula he is telling students to use. Photo 84
181.		Iyongiyo ya des…(*that one)*	A student cuts in loudly, pointing to the part he is referring to. Photo 85

182.	Ni uko ari ubwa mbere muyibonye …*(It is because you saw it for the first time)*		
183.		Icyo gice kindi kirakomeye *(That step is difficult)*	
184.	Ari ibintu mwi settinzemo mu mitwe mwamaze *(You have made it up in your mind for a long time)*		
185.		/Oya (no)/	Photo 86
186.	/igihe/ mufata Ariko …iyi niyo yoroshye (*but this one is simple*) Siyo yoroshye? *(Is it difficult?)*		Teacher gestures behind him to the formula at the board as he talks. Photo 87.
187.		Iroroshye Iih..N iriya… (That is simple)	Student gestures emphatically towards the board as he calls out to the teacher. Photo 88

188.	Iyi niyo iri very very simple *(this one is very very simple)*		Teacher walks back to the middle of the board and underlines the original formula on the board as he talks. Photo 89
189.		simple simple	Two students seated front right repeat ‘simple, simple’, the teacher nods towards them as they talk.
190.	Sibyo? *(isn’t it?)*		
191.		Yego *(yes)*	A single student loud
192.		Yii.. Iroroshye *(That is simple)*	The same student points again to his preferred formula. Photo 90
193.	Ih?		The teacher asks him to repeat
194.		Yii.. Iroroshye *(That is simple)*	The same student points again to his preferred formula. Photo 90
195.	….. Nta kibazo *(There is no problem) ……..*		The teacher moves to a desk at the front left. He picks up the coursebook, and stands looking into it for 8 seconds.

196.	Ubu ni ukuvuga ngo…Buri cuboid iba ifite six rectangles…sibyo? ..ariho twakwita six face Sibyo? …Sibyo? … *(That is to say every cuboid has six rectangles called six face. Isn't it? Isn't it?)*		Teacher moves back to the board as he talks, holding the coursebook open in front of him. He writes '6 rectangles' and then '6 faces' below it in the middle of the board next to his diagram as he says the words.
197.		Sibyo (isn't it?)	One student echoes, as if resisting the normal order.
198.	Face zi,, za cuboid ziba ziri? *(Cuboid sides are?)* ..		Teacher is still writing '6 faces' as he talks
199.		Rectangle ..	
200.	Rectangle ………..(12 seconds)		After he has said 'rectangle', and finished writing '6 faces' the teacher steps back and looks into the coursebook which he holds open in front of him. He moves back to the board and numbers the example 1, and then writes a number two in the remaining blank section of the blackboard for the example to come.
201.	Ka tujye kuri volume (Let's look at the volume)		Teacher walks back to the left side of the room, and addresses the class from there.

202.		/Tugiye kuri volume/ (We are going to find the volume)	T writing up new section from coursebook on the board (138 seconds)

Appendix G Coursebook pages: Surface area of cuboids

7 SOLIDS

Key unit competence

By the end of this unit, I should be able to select and use formulae to find the surface area and volume of solids.

Unit outline

- Properties of solids.
- Surface area and volume of a prism, pyramid, cylinder, cone and sphere.
- Formulae for surface area.

In Primary 5 and 6, you were introduced to designs and construction of nets of cuboids and other prisms. In this unit, we are going to further our skills on determination of areas and volumes.

7.1 Properties of solids

Activity 7.1

Work in groups

1. Use a Mathematic dictionary or the internet to research the word polyhedra (singular polyhedron).
2. List the properties of polyhedra.
3. Name and describe some examples of polyhedra.
4. Discuss your findings with your partner.
5. Make a summary of your findings and then share it with the rest of the class.

From Activity 7.1, you should have learnt that polyhedron is any 3-Dimension figure that has a flat surface for each face. Prisms and pyramids are examples of polyhedral. The majority of packages you see in everyday life are examples of **polyhedra**. These and other 3 – Dimension figures are called **solids**.

Activity 7.2

Work in pairs.

- Use your dictionary to find the meaning of the words: face, edge, vertex.
- Observe the closed cartons provided by your teacher. Identify the parts of the cartons and name them

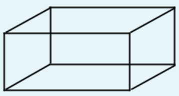
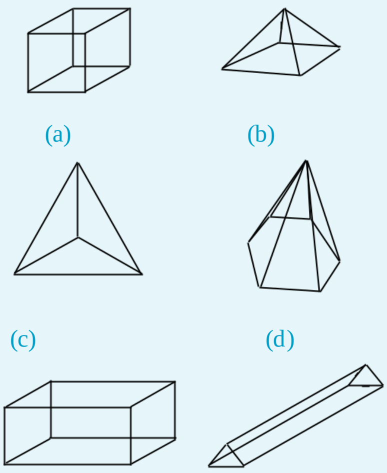


Fig. 7.1

- Use Fig 7.2 (a – j) below to investigate certain facts about some common solids as follows.



(a) (b) (c) (d) (e) (f)

Fig. 7.2

154

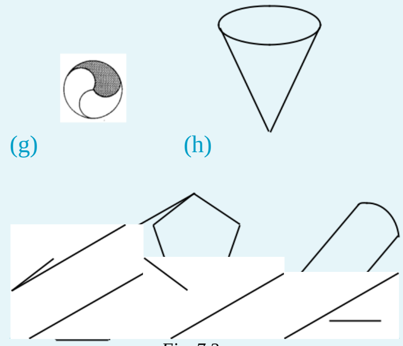


Fig. 7.2

(a) State the number of:

 (i) faces

 (ii) edges

 (iii) vertices that each figure has.

(b) Describe each shape and suggest a name for it.

(c) Which of the solids do not represent a polyhedron?

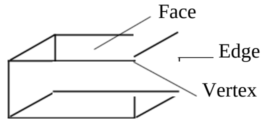
Discussion

1. Which of these solids are polyhedra?
2. List down all the prisms in Fig. 7.2.
3. List all the pyramids in the figure.
4. Which solids in Fig. 7.2 are hexahedra?
5. Are there any pentahedra? If so which are they?

From activity 7.2, you should have come up with observations similar to the ones listed below:

1. Cuboid

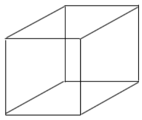
It is a solid bounded by three pairs of identical faces which are all rectangles. Sometimes, a cuboid is referred to as a 'rectangular box' or a 'rectangular block, Fig. 7.2 (e).'



2. Cube

It is a solid bounded by six identical faces which are all squares and equal.

A cube is a special type of cuboid, and it may sometimes be called a 'square box' Fig. 7.2 (a).

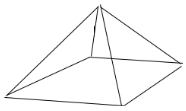


3. Pyramid

It is a solid figure with triangular slanting faces which meet at one point, called an apex or vertex, above a polygonal base.

A pyramid is always named after the shape of its base. Thus, there are triangular-based pyramids (tetrahedra), square and rectangular-based pyramids, pentagonal-based pyramids, and so on.

If the pyramid has its vertex vertically above the centre of the base, it is called a right pyramid Fig. 7.2 (b) and (d).



4. Tetrahedron

This is a solid figure with four faces which are all triangles. Therefore, it is a pyramid with a triangular base. Fig 7.2 (c).

5. Every polyhedron has more vertices than edges.
6. Every polyhedron has more vertices than faces.

From the activity, you have learnt that;

The line at which two faces (f) of a polyhedron meet is called an edge (e).

Edges meet at a point which is referred to as a vertex (plural: vertices) (v).

Note: f + v = e + 2

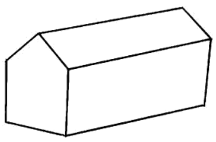
The relation f + v = e + 2 is named after Leonhard Euler (1707–1783). Euler was a gifted Swiss Mathematician, and is reputed to have produced the highest number of works in Mathematics and History. He is rated as the first modern Mathematical universalist.

The relation is called Euler's relation.

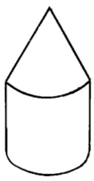
Exercise 7.1

Working in pairs, discuss this exercise. Identify all the basic solids that compose the shapes in Fig. 7.3.

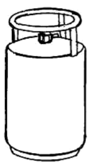
1.



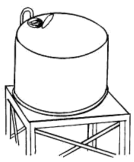
2.



3.

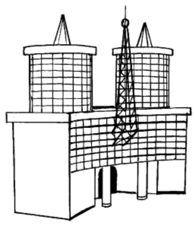


4.



5.

6.



7.

Fig. 7.3

7.2 Surface area of solids

You are already familiar with the use of accurate nets to determine area of cuboids.

(a) Surface area of a cuboid

Activity 7.4

Work with a patner

• Draw the cuboid in Fig 7.4 below.

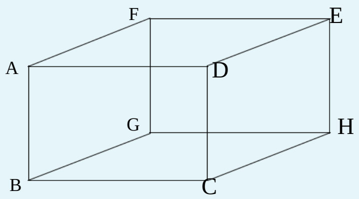


Fig 7.4

- Draw a well labeled net of the cuboid above.
- How many faces does the cuboid have from the net?
- How would you calculate the area of the cuboid using the net?
- Use the net to calculate its area in terms of l, w, and h.

From Activity 7.5, you have learnt that: the surface area of a cuboid of length l, width w and height h (Fig. 7.5), is given by $2lw + 2lh + 2wh$ *e.g.*

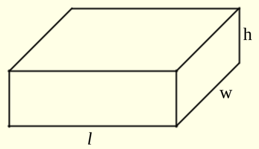


Fig. 7.5

The net of the cuboid will be as follows:

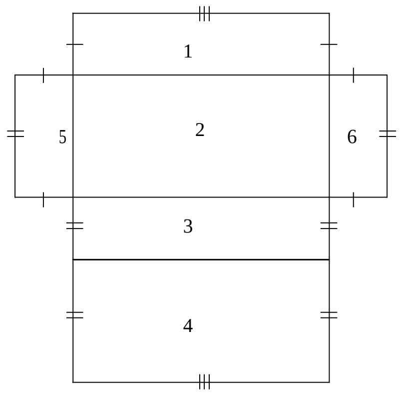


Fig 7.6

A cuboid has 6 faces.

The sum of the areas of the six faces gives the surface area of a cubiod.

Example 7.1

The net of a cuboid consists of a series of rectangles. How many rectangles are there? What is the surface area of the cuboid if it measures 6 cm by 3 cm by 2 cm?

Solution

Fig. 7.7 shows the sketch of the cuboid described in this example.

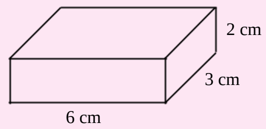


Fig. 7.7

Fig 7.8 shows a possible net of a cuboid which measures 6 cm by 3 cm by 2 cm.

It is composed of three pairs of rectangles i.e. 6 rectangles.

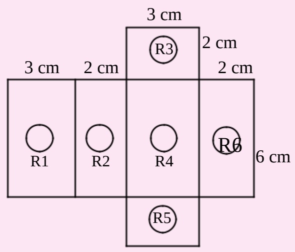


Fig. 7.8

The surface area of the cuboid = sum of the areas of all the rectangles that comprise the net.

Area of rectangle R1 $= 6\text{ cm} \times 3\text{ cm}$

$= 18\text{ cm}^2$

Area of rectangle R2 $= 6\text{ cm} \times 2\text{ cm}$

$= 12\text{ cm}^2$

Area of rectangle R3 $= 3\text{ cm} \times 2\text{ cm}$

$= 6\text{ cm}^2$

Area of rectangle R4 $= 6\text{ cm} \times 3\text{ cm}$

$= 18\text{ cm}^2$

Area of rectangle R5 $= 3\text{ cm} \times 2\text{ cm}$

$= 6\text{ cm}^2$

Area of rectangle R6 $= 6\text{ cm} \times 2\text{ cm}$

$= 12\text{ cm}^2$

Total surface area = $18cm^2 + 12cm^2 + 6cm^2 + 18cm^2 + 6cm^2 + 12cm^2 = 72\ cm^2$

Surface area of the cuboid = $72\ cm^2$

(b) Surface area of a cube

Activity 7.5

Working with a partner, draw the net of a cube of sides l unit.

Use your net to calculate the total surface area of the cube.

Compare your answer with those of other groups in your class.

Discussion

1. Describe a cube to your friend.
2. Compare the surface area of a cuboid to that of a cube. What do you notice?
3. Is there a shorter formulae to calculate the surface area of a cube?

Learning point

By definition, a cube has six faces that are identical. The faces are all squares. Therefore, total surface area = area of one face x 6. If the length of each face is l units,

Area = $l \times l \times 6$

= $6l^2$ square units

Example 7.2

Find the surface area of a cube of sides 5 cm.

Solution

Fig. 7.9 is the sketch of the cube.

The cube has 6 identical faces each of area $5\ cm \times 5\ cm = 25\ cm^2$

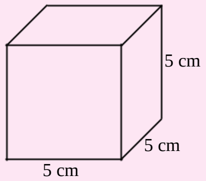


Fig. 7.9

$SA = 6l^2$

$= 6 \times 5\ cm \times 5\ cm$

$= 150\ cm^2$

Example 7.3

A cube has a total surface area of 96 square cm. Find the length of the side of the cube.

Solution

The length, the breadth and the height of a cube are all equal.

Let $l = b = h = x$ *units*

Fig 7.10 shows the cube

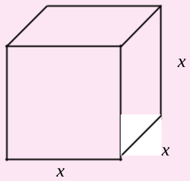


Fig 7.10

Number of faces of a cube = 6 Area of each face = $x \times x$

$\therefore$ *Total surface area*

$= x \times x \times 6$

$= 6x^2$

$\therefore 6x^2 = 96\ cm^2$

$x^2 = \frac{96}{6}$ (divide both sides by 6)

$x^2 = 16\ cm^2$

$\therefore x = 4\ cm$

$\therefore$ *The length of the side of the cube is 4 cm.*

Appendix H Respondent survey

Instructions

1. Read each statement.

2. Show your opinion about the statement by marking one of the numbered columns next to the statement, as follows:

   1= Strongly agree

   2= Agree

   3=Neither agree nor disagree

   4=Disagree

   5=Strongly agree

3. Add a comment to explain your opinion.

Example:

Statement	1	2	3	4	5	Your comments
1. You have clearly defined learning objectives for each lesson	X					I always know the lesson objective before the lesson. I write them in the lesson plan.

4. Email the completed survey to Rachel: bowdenrka@posteo.de

5. Suggest a day and time when we can talk on WhatsApp or Zoom (for maximum 1 hour)

Thank you!

The survey

Statement	1	2	3	4	5	Your comments
2. You have clearly defined learning objectives for each lesson		X				I useLearning Objectives to indicate what learners gained
3. You begin lessons by telling students the learning objectives, and showing them key mathematical terms and definitions.			X			I begin the lesson by introduction and objectives have written in lesson plan

4. Then, students see and do mathematical exercises which show them the mathematical concepts.	X					Students do exercises referring to what teacher thought
5. You finish lessons by summarising learning objectives and inviting students to ask questions.	X					In conclusion I gave learners group work activity (or evaluation)
6. In your lessons, students learn mathematics by doing exercises and watching other students doing exercises.		X				Students collaborate each other
7. Students must watch and listen carefully in order to learn.	X					All students must be concentrate in the lesson
8. You (the teacher) observe students and respond if you think they do not understand. For example, by giving more explanation or repeating.	X					I repeat the lesson if necessary
9. Your job is to teach these students mathematics not English			X			Some time we use mathematical term but we use English in teaching - learning mathematics
10. You always use English for mathematics terms (for example, 'frequency polygon', 'mid-point') and definitions.	X					We use mathematical term where are needed
11. You use Kinyarwanda, diagrams and demonstration of examples to help students understand English and mathematics.	X					Because English is difficult to some students we mixt kinyarwanda and English
12. You allow students to use English and Kinyarwanda in lessons				X		In order to help students can use kinyarwanda in a little time
13. English is not a big problem for teaching and learning mathematics	X					I know it very well
14. English is easy for you	X					Yes
15. You always use the coursebook in lessons		X				Some time I make research on internet
16. You choose parts of the coursebook to use in the lesson	X					According to the topic we have
17. The groupwork activities in the coursebook are not always useful for teaching and learning mathematics		X				Some time we use exercises from any where

18. Few students own a coursebook			X			The coursebook are Very expensive
19. Few students can understand the coursebook without help because it is in English		X				Some students go in library to learn thereselve
20. The coursebook is a useful resource for these lessons	X					Because the coursebooks are obtained easily

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