An Examination of Secondary School Intervention in Mathematics: Policy and Practice

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ABSTRACT

The rationale for this study is to examine the under-researched area of the relationship between recent national policy reforms around the curriculum and secondary school practice in relation to GCSE mathematics interventions for underachieving students in the UK. This has been an area of concern for some time, especially for teachers, as much previous research has focused on educational outcomes and barriers to learning rather than the learning processes involved. This study involves researching the theme of mathematics intervention provision in one secondary school and will examine school responses, as well as teacher and student perspectives and aims to answer the central research question: *given the nature of secondary schools in England, why and in what ways do students underachieve and disengage in GCSE mathematics and what, if any, is the impact of interventions with students and teachers?* The research findings in this study will contribute to the disciplines of education and mathematics primarily and several related sub-disciplines.

Three socio-mathematical norms, coherency, justification, and computational strategies were identified in the intervention phases. To establish these norms, the teachers, in the study, employed direct prompts and modelling. Therefore, one of the teachers and myself established a conducive environment, systematically taught the students mathematical skills and used practices that built upon each other in our concept-focused use of mathematical tasks. The results of this study offer insight into how mathematical discussions, tasks, and practices can be more optimally conceptualised. They also underscore the importance of the teacher's subject knowledge in enabling these norms to emerge.

The literature draws mainly from the areas of education, education policy, secondary education mathematics education, teacher pedagogy, academic intervention strategies and evaluative studies in school and underachievement in them. Key policy documents and scholarly literature at regional, national, and international levels of analysis are reviewed. From this, two divergent models of secondary school intervention approach emerged: the traditional transmission model which links more to an 'outcomes' approach which is exogenously driven by a managerialist state paradigm versus the student-centred connectionist approach favoured for this study driven by the professional approach of the teachers, which is more focused on the endogenous environment of the school. Such approaches to intervention strategies within secondary schools are at the nexus of this debate. One overarching theoretical model which provides a way of conceptualising student mathematics intervention strategies within the complex endogenous and exogenous landscape of secondary education is the Health Promoting School (WHO, 1998) which adopts a school approach to change in terms of the interconnectedness of the curriculum, teaching and learning, environment and ethos but, also, significantly, family and community partnerships. This collaborative working with external stakeholders is a vital aspect in relation to the usefulness of this model for analytical purposes and the interrelatedness of the micro, meso and macro levels.

In terms of methodology, this study adopts a mainly qualitative approach in the interpretivist and constructivist epistemological tradition, using an action research approach and mixed research methods. Fieldwork involving a sample of five teacher and ten student participants was undertaken. This included two focus group interviews with students, two semi- structured one-to-one interviews with teachers, and one classroom observation. Data were gathered in Majac Secondary School from students of similar demographics and socioeconomic characteristics, including both high-and low-achieving students. Several additional qualitative and quantitative data collection methods were used, including school institutional documentation review. In addition, data were also gathered in action research cycles evident in the two intervention chapters.

Key findings focus on the significant impact of mathematics strategies at the school meso level and demonstrate that there have been many changes in practice at this level, to accommodate changes in policy at national macro level, and, also as a consequence, changes at the student micro level. Specifically, the case study secondary school has engaged in extensive institutional environmental planning and has developed a range of policies, structures and processes for the implementation of intervention strategies in practice. In addition, the school has responded to national policy by adapting or re-structuring curricula and learning opportunities for greater access by underachieving students to interventions and a range of new collaborative partnerships have successfully evolved. These findings suggest that intervention strategies have resulted in a degree of change at the level of the school as an institution, although there was some evidence of continuity of existing and more traditional practices.

Hands-on activities, a cooperative environment and teachers' understanding of concepts being taught are cited as the some of the recommendations about the success of interventions undertaken in this research study.

Keywords: socio-mathematics, achievement, intervention, performance, cooperative learning

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List of Acronyms

(A- level) Advanced Level
(ACME) Advisory Committee on Mathematics Education
(AQA) Assessment and Qualifications Alliance
(BERA) British Educational Research Association
(CCK) Common Content Knowledge
(CK) Curriculum Knowledge
(COVID 19) Coronavirus Disease 19
(CPD) Continuing Professional Development
(DCSF) Department for Children, Schools and Families
(DfE) Department for Education
(EAL) English as an additional language
Edexcel- the name is a portmanteau term combining the words education and excellence
(EFF) Education Endowment Foundation
(EMU) Extending Mathematical Understanding
(FE) Further Education
(GCE O level) General Certificate of Education, Ordinary Level
(GCE) General Certificate of Education Advanced
(GCSE) General Certificate in Secondary Education
(HE) Higher Education
(HoD) Head of Department
(HPS) Health Promoting School
(ICT) Information and Communications Technology
(IWB) Interactive Whiteboard
(KS2) Key Stage 2
(KS3) Key Stage 3
(KS4) Key Stage 4
(LAC) Looked after Children
(MLD) Mathematics learning difficulties
(NC) National Curriculum
(NCETM) National Centre for Excellence in Teaching Mathematics
(NCTM) National Council of Teachers of Mathematics
(NETP) National Education Technology Plan
(NFER) National Foundation for Educational Research
(NQTs) Newly Qualified Teachers
(NRC) National Research Council
(OCR) Oxford, Cambridge, and RSA Examinations
(OECD) Organisation for Economic Co-operation and Development's
(OERs) Open Educational Resources
(Ofqual) Office of Qualifications and Examinations Regulation
(Ofsted) Office for Standards in Education, Children's Services and Skills
(PBL) Problem-Based Learning
(PCK) Pedagogical Content Knowledge

(PGCE) Post Graduate Certificate in Education
(PISA) Programme for International Student Assessment
(PK) Pedagogical Knowledge
(PP) Pupil Premium
(RME) Realistic Mathematics Education
(RSL) Raising Standards Leader
(RTI) Response to Intervention
(SA) South Africa
(SCK) Specialised Content Knowledge
(SEMISM) Socio Ecological Model of Intervention in Secondary Mathematics
(SEND) Special Educational Needs and Disability
(SES) Socio-Economic Status
(SLT) Senior Leadership Team
(STEM) Science, Technology, Engineering and Mathematics
(TIMSS) Trends in International Mathematics and Science Study
(TPCK) Technological pedagogical content knowledge
(UK) United Kingdom
(US) United States of America
(WJEC) Welsh Joint Education Committee

CHAPTER ONE: OVERVIEW OF THESIS

1.1 Rationale

How do people learn? Arguably this question, investigated in the well-known National Research Council Book, *How People Learn*, (NRC, 2000) is the most fundamental question in education. Fostering learning is a foundational goal of education and is often the standard by which its efficacy is assessed. Because of the central importance of learning, other aspects of education, such as pedagogy, curriculum, task selection, class size, and use of technology, are commonly evaluated by their effect on learning. Changes in these areas tend to be justified by a purported beneficial impact on learning.

For most of the 20th century, education was dominated by the behaviourist learning theory (Sperry, 1993). Behaviourism attempted to make psychology an objective, hard science by focusing strictly on observable evidence, for example, behavioural evidence (Miller, 2003). In the following decade, cognitivism's influence spread beyond the field of psychology into many other fields, such as education (Sperry, 1993). Cognitivism abandoned behaviourism's restrictions on non-observable mental phenomena and legitimised the notions of consciousness and theories about inner mental processes. The behaviourist view of learning as a change in behaviour was rejected in favour of a new perspective that emphasised "what learners know and how they acquire it" (Jonassen, 1991: p. 6). The widespread acceptance of cognitivism in the 1970s allowed a new theory of learning called constructivism to rapidly gain influence (Steffe and Kieren, 1994). Although constructivism influenced many different fields, I focus here solely on its impact in the field of mathematics education within a specific school in England, the United Kingdom (UK).

By the mid-1990s, constructivism was acknowledged, even by its critics, to be a major, if not the dominant, theory of learning in the mathematics education community (Lerman, 1996). Constructivism's foundational assumption is that an individual constructs all of his or her own knowledge, rather than receiving it from external sources. As a sense-making being, the individual is constantly creating mental models, called schemas, in an attempt to organise experiences into a coherent whole (von Glasersfeld, 1989a). An important implication of constructivism is that the individual necessarily plays an active role in learning as he or she continually builds and modifies schemas (Perkins, 1999).

This study concerns an action research project which investigates intervention strategies to support underachieving students completing the UK General Certificate in Secondary Education (GCSE) mathematics (typically aged 16 years), with a specific focus on students who are currently predicted to just miss out on a '*good GCSE pass*' which is defined as a 'grade 4' in the new scale or a 'grade C' in the old scale. The purpose of this research study was to discover and describe the components of the mathematics intervention that resulted in increased mathematics achievement for secondary school student participants in an effort to inform decisions regarding curriculum improvements and to provide insight to other teachers investigating mathematics interventions.

1.2 Forms of Constructivism

As a researcher/teacher, constructivism is important as it allows student responses to drive lessons, shift instructional strategies, and alter mathematical content. One of the earliest manifestations of constructivism to gain prominence in mathematics education was radical constructivism, promoted heavily by Ernst von Glasersfeld (1984, 1989a, 1989b, 1995). Radical constructivism made the additional claim that there is no objective reality external to and independent of the individual (von Glasersfeld, 1995). Truth as a correspondence with an external reality was replaced by the pragmatic concept of viability: 'truth' was now what works for an individual's subjective reality. Other constructivists Cobb and Yackel, (1996), combined constructivism with sociocultural theory to create a pragmatic blend of the two, called the emergent perspective. Whereas constructivism focuses on the individual mind and how it creates knowledge, sociocultural theory places primary focus on the broader sociocultural community (Cobb, 1994).

1.3 Implications and Effects of Constructivism

Since constructivism's rise to prominence, many teachers, researchers, and others in the field of mathematics education have attempted to determine its implications for pedagogy, a task that has proven more difficult than might be anticipated. Simon (1995: p.114) observed that while constructivism provides a useful framework for thinking about learning, "it does not tell us how to teach mathematics; that is, it does not stipulate a particular model". von Glasersfeld (1995: 177) agreed with Simon (1995) when he wrote that constructivism "[can] not produce a fixed teaching procedure. At best it may provide the negative half of a strategy". However, many constructivists, including Simon and von Glasersfeld, agreed that constructivism does carry general implications for pedagogy. Since individual students actively construct knowledge, the teacher should continually strive to understand what schemas the students are constructing in response to classroom activity. Student mistakes are an opportunity for exploration rather than immediate evaluation since they offer insight into how students are attempting to make sense of their experiences (von Glasersfeld, 1989a). More classroom discussions in general also aids the teacher in discovering student schemas.

Since knowledge cannot be directly transmitted via language, the teacher should place less emphasis on direct instruction (which puts the students in a passive role) and greater emphasis on active student engagement in classroom tasks (von Glasersfeld, 1995). Social interactions are the most common source of worries (which then result in learning), so teachers should allow students to collaborate more frequently in discussing and solving problems (von Glasersfeld, 1989a). Therefore, the Phase One and Phase Two mathematical intervention activities focused on active participation from the students in their small groups as students are naturally sense-making beings, so repeated drill of procedures and algorithms, lack of understanding, should be prevented.

Teaching mathematics has been approached from many different disciplines, for example, cognitive psychology, neuroscience, biology, genetics, although some, such as mathematics teaching, science teaching and educational psychology construct closer bridges between their results and daily practice in the classroom. It must be considered that each of the different disciplines focuses on different variables of the teaching-learning process, the student, the context, the teacher. Since the teaching process is very complex, the intervention programs that I have put in place for Phase One and Phase Two in this study, must try to respond to all the variables involved in the process, being aware that modifications may occur while being implemented in the classroom or the activity centre (Simplicio et al., 2020).

Constructivism still leaves quite a bit unsaid regarding specifics of the mathematics teacher's role in the classroom. As teachers have tried to adapt their pedagogy to be consistent with constructivism, one particular issue has arisen repeatedly over the years, usually playing itself out in the following manner: The teacher has particular Content Knowledge (CK) that he or she would like to students to attain. In keeping with constructivist principles, the teacher wishes to avoid direct instruction and instead allow the students a more active role in the classroom, with the goal that the students will eventually construct the desired content knowledge for themselves. However, allowing the students a more active role in the classroom inevitably brings greater unpredictability (Simon, 1995). Perhaps the students hit a conceptual roadblock and give up. Perhaps they focus on an irrelevant detail that leads them on an unrelated tangent. Or perhaps they reach a contradictory conclusion without being aware of it. The teacher then struggles with how to bring the students to construct the desired content knowledge without simply reverting to direct instruction and thereby placing the students in a passive role. Therefore, this study aims to improve students' mathematical performance through interventions which will lead to students improving their understanding of mathematical contents, specifically in problem solving tasks. A further, brief discussion follows in Chapter Three where I emphasise Constructivism as a paradigm and how it links with Interpretivism.

1.4 Effective Mathematical Discussions

One of the more prominent emphases in the Teacher Standards was that student learning occurs through mathematical discussion. Some researchers even called discussions a "central tenet" (Williams and Baxter, 1996, p. 22). Communicating mathematically clarifies thinking and forces students to engage in doing mathematics. As such, communication is essential to learning and knowing mathematics (NCTM, 1989, p. 214).

Silver and Smith (1996) observed that communication is both more widespread and more central to mathematics education reform efforts than ever before. Hufferd-Ackles, Fuson, and Sherin (2004: pp. 81-82) made the following observation:

> The successful implementation of [NCTM] reform requires that teachers change traditional teaching practices significantly and develop a discussions community in their classroom…. research [over the past decade] describes the many dilemmas that teachers face in trying to implement [the NCTM vision], and more specifically in establishing a discussions community.

Recently, Baxter and Williams (2010: p.7) wrote that "over the past two decades… suggested [NCTM] reforms in curriculum, instructional methods, and assessment techniques have become the focus of both research and policy discussions", and then immediately proceeded to mention the emphasis on discussions. It is reasonable to conclude then that the NCTM's vision has prompted a continuing emphasis on mathematical discussions within the mathematics education community. However, the NCTM described their proposed discussions by listing its qualities, for example, the source of authority for these discussions were to be mathematical reasoning rather than teacher or textbook. NCTM, 1991 states

> that something is true because the teacher or the book says so is the basis for much traditional classroom discussions. Another view, the one put forth here, centers on mathematical reasoning and evidence as the basis for discussions (p. 34).

When studying mathematical discussions, many researchers have focused on similar conversational qualities. For example, Baxter and Williams (2010: p.14) specifically looked for "the extent to which discussions focused on sense-making" as well as "the site of intellectual authority". Hufferd-Ackle, et al (2004: p.88) conception of desirable mathematical discussions was one where "math sense becomes the criterion for evaluation". O'Connor et al (2014: p.402) emphasised mathematical coherency when they stated that "to facilitate productive mathematical discussions, teachers must engage in behaviour that helps students build from their own understandings toward appropriate understandings of mathematical ideas". Despite the focus on communication within the mathematics education community, teachers have not always been successful in their efforts to create positive discussions in their classrooms.

Studies, such as, (William and Baxter, 1996; Nathan and Knuth, 2003) have documented classrooms where teachers successfully increased the amount of student discussions while failing to foster the qualities of productive discussions. In Phase Two of the study the students in their small groups were able to have mathematical discussions with their peers from different ability settings. These discussions assured that all students were actively participating in the mathematical activities. However, these discussions did not lead to the creation of common knowledge in the way that we (Ms Hanekom and I had hoped it would be. In some cases, the discussions became for students an end in itself. In others, it became another unnecessary requirement.

1.5 Social and Social Mathematical Norms

Each classroom, at Majac secondary School, has its own microculture with its own norms that belong to this microculture. It is these norms that characterise every kind of activity and discussion in the classroom. What makes a mathematics classroom different from any other classroom is the nature of norms, rather than their existence or absence. This study aims to identify the socio-mathematical norms that belong to different mathematics learning environments based on the qualitative design.

First, social norms express the social-interaction aspects of a classroom that become normative (Yackel, Rasmussen and King, 2000). These norms are common norms that can be enacted in any field (Cobb and Yackel, 1996b). For example, explaining and justifying solutions, identifying and stating agreement, trying to make sense of others' explanations, expressing disagreement on ideas, are social norms for discussions where the whole class participates (Cobb and Yackel, 1996a). Furthermore, social norms describe regularities in group social behaviour and function as rules or criteria by which to judge acceptable social behaviour. As Sfard (2000: p. 170) points out, group behavioural consistencies and group social expectations develop simultaneously. Sfard explains, "by incessantly repeating themselves, the unwritten and mostly unintended [social] rules shape people's conceptions of 'normal conduct' and, as such, have a normative impact". As an easy statement, as we repeat the same behaviours again and again, we come to expect them. The presence of social norms in a classroom does not guarantee that effective mathematical discussions will occur. Multiple studies (Williams and Baxter, 1996; Kazemi and Stipek, 2001; McClain and Cobb, 2001; Nathan and Knuth, 2003) documented classrooms where social norms were present and student discussions was plentiful yet mathematically unproductive. Together, the studies mentioned, above, demonstrate that effective social norms alone do not suffice to produce mathematically effective mathematical discussions.

Second, socio-mathematical norms state normative understandings related to mathematical reality (Yackel et al., 2000). Although socio-mathematical norms pertain to mathematical activities, they are different from mathematical content. They deal with the evaluation criteria of mathematical activities and discussions unrelated to any particular mathematical idea (Cobb et al., 2001). Normative understandings regarding things in classrooms that are mathematically different, complex, efficient, and elegant are socio-mathematical norms. In addition, things that are accepted as a mathematical explanation and justification or regarded as a mathematically different, complex, or efficient mathematical solution are considered to be socio-mathematical norms (Cobb and Yackel, 1996a, 1996b; Cobb, 1999; Yackel et al., 2000). Besides, socio-mathematical norms are established through interactions such as social norms (Yackel et al., 2000). Therefore, In Phase One, the six intervention lessons, the students participated actively through hands on engagement and in Phase Two at the mathematics camp the students participated in their small groups to enhance their mathematical abilities, beliefs and values which enabled them to act as an autonomous member of the small group they were working in (Bowers et al., 1999; Cobb and Yackel, 1996b). Therefore, socio-mathematical norms involved ways of making decisions amongst themselves (in the small groups), and they enabled the rest of the group to talk about and analyse the mathematical aspects of activities in the mathematics sessions when feedback was given. Constructing socio-mathematical norms is pragmatically important and provides the basis for a classroom's mathematical microculture; interaction between the teacher and students, and between students themselves (Yackel and Cobb, 1996; Askew 2016).

1.6 The Process of Establishing Norms

A classroom is defined as a complex environment that accommodates individuals who come together with the aim of constructing a learning community (Levenson, Tirosh, and Tsamir, 2009). Like every community, such as Majac Secondary School community, a classroom constitutes and develops an association of social relations and its own microculture (Gallego, Cole, and The Laboratory of Comparative Human Cognition, 2001; Lopez and Allal, 2007). The microculture of a mathematics classroom contains social interactions and the construction of mathematical meaning (Voigt, 1995). It does not exist separate from the mathematical activities of a classroom community (Cobb et al., 1992). Its characteristics depend on norms, patterns, and regulations that are difficult to change, such as students' attitudes (Voigt, 1995). Social and socio-mathematical norms, together with a classroom's mathematical practices, constitute the classroom microculture where individual and collective mathematical learning occurs (Cobb et al., 2001) and this was no different in classrooms at Majac Secondary School. Hence, many of the beliefs and expectations that the students tend to bring into the classroom were not conducive to constructive mathematical discussions. The process of trying to change unproductive norms can require substantial effort on the teacher's part.

Studies, such as Smith (2000) and Hufferd-Ackles et al (2004) and Sanchez and Garcia, (2014) explains that to change unproductive norms can require substantial effort on the teacher's part. Furthermore, Yackel and Cobb (1996) found that students may assume different criteria when justifying a solution strategy or use the same word with different understandings of its meaning or as in Smith's (2000) example, students may not recognise the importance or accuracy of an activity. These examples illustrate that the process of establishing productive norms can be difficult. It may require great effort on the teacher's part and even face student resistance. In light of this fact, it is important that the teacher adopts effective strategies when trying to establish productive norms.

1.7 Role of Intervention

I have selected the aspect of intervention because achievement in mathematics education continues to be a growing concern in the UK. Schools continue to struggle with the best methods and strategies to implement effective mathematics programs while working towards closing achievement gaps for those students who are not meeting the expected target grades. There is little information for the implementation of intervention programs at the secondary level, and more importantly, it is a significant challenge at this level. Since secondary level mathematics classes tend to be grouped by ability, in most state comprehensive schools, the content is presented at the perceived ability level of the students in that class, preventing students from experiencing opportunities which higher achieving peers have access to.

The National Council of Teachers of Mathematics (NCTM, 2011) recognises the need for equity in mathematics, specifically in the form of high expectations for all students, allowing for opportunities to learn mathematics with rigorous, meaningful and challenging experiences. Schoenfield (2004) holds that knowledge of any type, but specifically mathematical knowledge, is a powerful vehicle for social access and social mobility; therefore, the lack of access to mathematics is a barrier that leaves people socially and economically disenfranchised. In an effort to increase access and equity in mathematics instruction, The National Mathematics Advisory Panel Final Report (2008), recommends that schools work towards preparing all students for algebra in grade eight (UK Year 9), requiring that students understand basic mathematical and problem-solving skills prior to the start of Year 9 and ensuring that they have mastered algebraic concepts prior to beginning high school. These interventions should be support-focused and help with improving student progress towards identified goals. Therefore, schools have an obligation to provide students with the best curriculum and hold high standards for all. This is true for an "all kids agenda", which includes believing all students can learn and grow from where they are currently. However, since not all grow at the same rate, same pace and with the same information, there is a need to individualise and personalise (Fuchs and Fuchs, 2008; Brown-Chidsey and Steege, 2010).

Therefore, this longitudinal study focusses on supporting an identified group of students and their teachers at Majac Secondary School over time to ensure a significant increase in student progress by quantifying the effectiveness of the involvement of students with the varying interventions against the output of their grades. The final results will uncover which interventions are worth the investment of teacher resources as well as those which support students to make the progress they are capable of, not just to boost the school's performance in league tables but to provide students with the best possible education.

1.8 The Research Objectives

This research has the following objectives:

- To **create new knowledge through original research** of mathematics intervention initiatives based on action research in one case study secondary school in the United Kingdom (UK);
- To **systematically analyse** student, teacher and school leader **perspectives** on intervention initiatives that have emerged in response to concerns to the changes in the mathematics curriculum by the Department for Education (DfE);
- To **conceptualise, design and evaluate pedagogical developments** in the school context that might impact on **student outcomes**, the curriculum, and the working practices of teachers;
- To **draw conclusions and make recommendations** for developments in **policy and practice** in the area of underachievement in mathematics at the student level, but also inform the level of the secondary school; and,
- To **provide direction and insights** that will inform **further research** in the area of access.

1.9 The Research Questions

Near the end of their article, Kazemi and Stipek (2001: p.79) made the following remark:

> Although we propose that at least four socio-mathematical norms worked together to create a press for conceptual learning, continued research may reveal other norms that contribute to a high press. It is also important to investigate, with longitudinal data, how socio-mathematical norms are created and sustained, and how they influence students' mathematical understanding.

Since this remark was made, many studies have focused on social and socio-mathematical norms, as well as their formation.

A longitudinal study (over five years), such as this study, analyses data over time. It may include intermittent analysis but widens its focus to consider the relationships between events happening over time. Because of its larger data set, a longitudinal analysis allows the researcher to make more encompassing assertions (Cobb and Whitenack, 1996). My study intends to use longitudinal data to analyse the central research question: *given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?* This research was carried out as an action research project based around ten student participants and five teacher participants at Majac (pseudonym used) Secondary School. The research consisted of two phases of interventions that took place alongside normal timetabled lessons.

Based on a review of the relevant literature in the field and guided by the overarching research problem, the following subsidiary questions have been developed to guide the analysis of this study.

(1) Why do students underachieve academically when the ability to achieve is present?
(2) What were the key participants' perceptions of their successes and failures in the study?
(3) What factors contribute to their psychological and academic needs?
(4) Why is it important to empower able underachievers?
(5) How can strategies and techniques help enhance student performance?

In analysis, these sub-questions will be treated chronologically, ultimately informing the central research question; the first focusing on why students underachieve; the second putting these descriptions into student context of their successes and failures; third, using the comments and descriptions to find out what factors contribute to academic failure, fourth, establishing why able underachieving students' needs to be empowered before finally considering what strategies and techniques can support underachieving students. All of these link to an assumed gap between practice and the student potential in terms of developing knowledge and understanding. This research intends to map out and better understand this gap, and in conclusion consider any possible ways forward.

It also acknowledges, how Bronfenbrenner's (1979) ecological model identifies the interconnected levels that influence human development. This model requires behaviour (*biological and psychological attributes; an individual's genetic heritage and personality* and development (*the physical, social, and cultural features of the immediate settings in which human beings live; family, school, and neighbourhood*) to be examined as a joint function of the characteristics of the person and of the environment (Moen, Elder, and Luscher, 1995).

Therefore, these sub-questions are divided into four distinct yet interconnected layers:

Table 1. 1 Interconnected layers

Research Question(s)	Interconnected layers	Bronfenbrenner level
1	International / Comparative level	Macro
2	National Level	Macro
3	Institutional Level	Meso
4,5	Individual Student Level	Micro

1.10 Background/ Context of Study

The inspection body for schools in the UK, Ofsted (2010) carried out a small-scale review of the intervention programmes available from the National Strategies for primary and secondary schools in 12 local authority areas chosen to feature urban and rural settings in the UK. They stated that intervention programmes are *off the shelf* resources, schemes of work, designed to be executed by teachers or other professionals to tackle a difficulty. Ofsted's (2010) findings concluded that there was no one effective intervention programme but that success was more likely to be determined by how well students were targeted, assessed, and monitored and how the overall programme was managed within the schools. Taking a whole school approach to intervention was a common message conveyed through the evaluation report, *Count Me In Too* (DfE, 2009), which focused on the impact of the project on teacher practice and pedagogy. It was found that a project like this had the potential to raise the standards of teachers' mathematical subject knowledge and practice across the whole school where all staff were involved to some degree in the programme.

Meanwhile, across the UK, tens of thousands of teachers still care deeply about the well-being and prospects of their students and are determined to provide them with the best and most humane education they can (Gillard, 2015). It is important to clarify that the research upon which this dissertation is based was conducted prior to September 2015 when the new mathematics GCSE was first implemented in secondary schools.

Since the school closures, as a result of the COVID-19 pandemic, the attainment gap widened due to students tend to have less access to technology, spend less time learning and have reduced support from parents/carers. The English government's response to the COVID-19 outbreak included closing schools to all students (except for children of keyworkers) in March 2021. During the period of school closure, education provision for students varied, but included online teaching, assignments marked remotely by teachers, lessons delivered by parents/guardians, and other supplementary learning activities (such as online materials or textbooks).

Stakeholders (including the Children's Commissioner, the Sutton Trust, the National Foundation for Educational Research (NFER), the Education Endowment Foundation (EFF), and the Education Policy Institute) have expressed concerns about the impact of the COVID-

19 outbreak on the achievement gap. All these stakeholders recommend collecting comprehensive data to shape targeted interventions, and to maximise collaborative approaches across families, community and equality groups to best respond to barriers to learning.

1.11 Relevance of Research and Contribution to the Field

This study is necessary as it will contribute to: (a) mathematics education; (b) teacher pedagogy and (c) intervention strategies in GCSE mathematics. It will further determine the nature of the intervention provision for secondary students in the UK which is an under-researched area. Therefore, this study provides an opportunity to contribute to the broad debate around schools/Senior Leadership Teams (SLTs) being dependent and responding to external pressures of a dominant competitive results-driven culture versus more independent professionals (teachers) focused on their pedagogical concerns. This research will also further develop our understanding of the implementation of access initiatives in a UK context. The aim of this study is to specifically examine the implementation of successful intervention provision and to demonstrate a positive approach being developed to reduce underachievement. Interventions yield most successful outcomes when they are integrated into daily practice and school culture, seek to engage all staff, reinforce skills outside of the classroom such as hallways and playgrounds, support parental engagement, and coordinate work with outside agencies (Ttofi and Farrington 2011; Weare and Nind 2011; Jones and Bouffard 2012; Barry et al., 2017).

At the beginning it was anticipated that data gathered from participants will:

i) Contribute to the knowledge base on student learning in secondary schools within an underachieving context;

ii) Benefit other secondary schools that may be interested in exploring their pedagogical intervention provision in the area of the mathematics;

iii) Provide recommendations for future development of teacher pedagogy, school practice and national policy in the area of underachievement in mathematics; and,

iv) Contribute to the growing body of studies in secondary school research and knowledge in a UK context (Clausen-May et al., 2000, Cawood, 2015).

The areas under examination, although crossing multiple disciplines, have a considerable degree of inter-relatedness. This research therefore has been informed by, and hopes to contribute to, the disciplines of mathematics and education primarily, and the sub-disciplines of mathematics education, education policy, mathematics education policy, politics of education, sociology of education, schools' policy and evaluative studies on schools and underachievement in them. The study also has implications for specific areas of mathematics education: curriculum development, professional growth, and training of teachers, and for future research. It may contribute to social policy, employment policy and public policy more generally.

1.12 The Focus of This Study

While only one school was the focus of this study, it was an in-depth action research analysis over a significant period. Therefore, the study could not survey pedagogical interventions in all schools for secondary school students. This dissertation does not assess the quality of the provision at the school in this study. The perspectives of other stakeholders including government and employers were not included.

As an action research project this research may benefit others (for example, secondary schools' mathematics communities, mathematics teachers, DfE) and improve the researcher's own practice: the findings cannot, by definition, be generalisable but will certainly be useful to secondary schools in similar comparable contexts.

1.13 Personal and Professional Background

Growing up in South Africa (SA) memories of school as a place where knowledge came from external sources (such as textbooks and teachers) and internalising this knowledge involved learning significant amounts of information by rote. I was in standard ten or Matric (SA school system before 2004) and the way forward came through my mathematics teacher who seemed to have a very different interpretation of what learning mathematics involved. She arrived for class, wrote a mathematical problem on the board, and then walked out again. A few minutes later, she walked in and the students were all on task, talking to each other and arguing about the problem. This was remembered as one of the first times that genuine excitement was experienced regarding learning. Being an independent student (even as a child) hands-on activity were enjoyed best as they gave time to integrate my thoughts with what I was learning. It was not until much later that I remembered my standard ten, mathematics teacher's unorthodox approach, as one that had resonated strongly with my desire to think and act for myself when learning.

Before I started my teaching career I worked for a year in a children's home, a safe place for vulnerable children. The institution was for boys between six and 18 years old. I used my teacher training skills to develop engagement and interaction with the children, but I learnt from the children and staff, as well, for example, how to manage and diffuse difficult situations between children, how to engage with children who the 'system' has forgotten. My discipline background is in mathematics with first and higher degrees in the discipline. Subsequently, I became an experienced secondary mathematics teacher, middle and senior school leader and then changed sectors to be a university lecturer of mathematics in education.

1.14 Conceptual Framework

The preferred conceptual framework for this thesis will be the Bronfenbrenner (1979) model, which can be described as ecological and contextualist. These terms are used, following Tudge and Hogan (2005), to denote understandings of the transactional relationships between people and their environments and the impossibility of studying individuals separately from the contexts in which they are embedded. As with Tudge and Hogan (2005: p.104), the research drew upon the ideas of Bronfenbrenner to provide a contextualist ecological theoretical basis for researching typically occurring everyday activities. Whilst his theory is sufficient for conducting and interpreting naturalistic observations of children's lives (for example, Tudge,et al., 2003, Tudge and Hogan, 2005, Tudge, 2008) a second theoretical perspective is added of my own, the Socio Ecological Model of Intervention in Secondary Mathematics (SEMISM) model, as a tool for researching pedagogical understandings and uses of secondary school students mathematics interventions.

1.15 Contribution to Research in the Field

While some research has been completed at the national policy level in this area, much less has been completed at the school level. Several gaps exist across the body of the literature, which were identified as part of the research (see Chapter Two, Literature Review). These include limited literature on intervention in secondary school mathematics and a tendency for research to focus on 'barriers' to intervention for GCSE mathematics students. Working collaboratively, and in partnership, is a relatively recent occurrence in secondary school mathematics. As a result, there is a dearth of evidence regarding effective collaborative secondary school mathematics intervention which largely remains undocumented. This research aims to provide a starting point for further work to capture effective collaborative working with teachers and students in secondary school mathematics. These descriptions will provide information on the process of involving different stakeholders (teachers, SLTs, governors, parents/carers) and the challenges and opportunities such ways of working provide at the level of secondary education, especially in an underachieving context.

1.16 Structure of Thesis

The structure of the remainder of the thesis is as follows:

Chapter Two - Review of Literature

Chapter Two reviews the literature drawn on in this research study. This literature primarily focussed on four areas:

- the macro-level global trends in secondary mathematics education. This section investigates policy and curriculum developments and examines comparative literature on secondary school students' participation in interventions;
- the progression of macro-level national developments;
- institutional meso-level studies on secondary mathematics intervention; and,
- micro-level impact on student intervention provision through social and social-mathematical norms.

The literature review will confirm that the study of intervention in secondary mathematics, is largely in an early developing phase with some useful theorising taking place in secondary schools in the UK (for example, Perryman et al., 2011; Taylor, 2016). Intervention strategies have been a key feature of the Secondary National Strategies since their inception in 2001. The National Strategies define the target group for intervention as: those students who are working below national expectations, but who have the potential to reach the levels expected of their age group if they are given timely support and motivation (Ofsted, 2009).

Chapter Three – Methodology

In terms of the methodology, this study adopts a qualitative approach in the constructivist and interpretivist epistemological tradition using the action research method. This chapter outlines the rationale for, and synopsis of, the range of methods employed to answer the research questions. Research which involved 10 student and five teacher participants was undertaken. In addition, this research was complemented (Green, Camilli and Elmore, 2006) by a review of Majac Secondary School mathematics departmental documentation (such as, departmental mission statement, policy, strategic plan, student records, student programme intervention evaluations). The following data collection methods are used: focus group interviews with students, semi-structured one to one teacher interviews and in class observations (Phase One only) with teachers and students. The research design is outlined, including the selection of teacher and student participants.

Chapter Four - Phase One: Findings, Discussions and Analysis

This chapter reports on the results of the initial data capture of semi-structured teacher one-to-one interviews, student focus group interviews and classroom observations with teachers and student participants. The findings from these interviews and observations relate to the research questions, as indicated below:

Table 1. 2 Findings Relating to Research Questions

Theme Number	Findings	Link to Research Question(s)
One	The impact of teachers' characteristics in maintaining levels of student (micro level) motivation and preparation for their future learning (meso level).	3,4, 5
Two	Student (micro level) active engagement (meso and exo levels).	1
Three	The lack of teacher subject knowledge (exo level) and students own personal characteristics to facilitate their learning (micro level).	1, 2, 3

Furthermore, several *sub-themes* (such as, pressured through lots of testing; teacher inability; use of technology) and *categories* (such as, stressed about learning, less textbook use; active learning; knowledge of subject) are identified.

Chapter Five - Phase One: First intervention

In Chapter Five the research describes the initial interventions (such as, targeted strategies and techniques, real life application, technology, simple equations) that took place in detail and the observations made during them.

> ***Theme One*** in the study is acknowledged in intervention lesson six. Teachers' motivation, Pedagogical Knowledge (PK) and Subject Content Knowledge (SCK) (exo level) supports the students learning and achievement (micro level).

Theme Two in the study is recognised in intervention lesson two as in the meso level the teacher provides strategies for learning and engage the students with real-life mathematics.

Theme Three in the study is identified from intervention lesson one. Pedagogical knowledge and subject content knowledge of the teacher is very important to support the student (micro level) through their learning journey and, the student ability settings (meso level) contributed to the teachers' subject knowledge to improve their achievement.

Chapter Six – Phase Two: Findings, Discussions and Analysis

This chapter presents and discusses the analysis of data gathered from the final student focus group interviews, and semi-structured teacher interviews that were developed following the initial intervention with the student participants. The findings in this phase were divided into the three themes, which reflect those in Chapter Four (Phase One).

The three themes were:

Theme One*:** Maintaining levels of student ***motivation and preparation for the future.

Theme Two: The need for ***active engagement***, less or no use of textbook driven lessons and different learning styles as teachers were instrumental in supporting them.

Theme Three*:** Lack of ***teacher subject knowledge and students own personal characteristics to facilitate their learning.

Chapter Seven – Phase Two: The Mathematics Camp - Intervention

Chapter Seven discusses the development of a framework for planning and organising intervention strategies through an outdoor mathematics camp for a group of GCSE students and evaluates the effect the camp had on the students' attitudes to mathematics.

Theme Two*:** The need for ***active engagement and working ***collaboratively*** with peers *and* in partnership with other outside agencies; supported by sub-themes, such as interactive demonstration, was identified in this section.

Chapter Eight - Discussions and Conclusions

Chapter Eight draws this study to a close and presents the final key conclusions drawn from the research findings and suggests recommendations for both future research and policy makers in a secondary school context. Each research question is discussed in relation to the relevant findings and the evidence reveals that there has been change in many areas of practice at meso level in response to macro-level strategies. Specifically, all student participants have engaged in mathematics intervention and have developed a range of subject specific skills, socio mathematical norms and abilities. These findings suggest that intervention in secondary mathematics initiatives have resulted in a degree of change at the level of the school, although there was also some evidence of continuity of existing practices. Chapter Two which follows provides an overview of policy trends and relevant literature.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

In the previous chapter, I introduced the reader to the research field within which this study lies. In this chapter, I establish Bronfenbrenner's ecological model of human development (Bronfenbrenner, 1979) to identify overlapping spheres of influence on school mathematics interventions. Following this, I provide an overview of policy and literature as it pertains to underachievement of GCSE mathematics students and how intervention can support their progress. To promote an understanding of the levels of influence on the field of achievement and intervention in mathematics, this chapter addresses four levels of analysis:

- Macro: international contextual influences;
- Meso: national influences, for example, at the school community;
- Exo: studies on teachers, for example, pedagogical knowledge and subject content knowledge (SCK) at institutional level; and,
- Micro: research on student mathematics provision in a secondary school.

These different levels of critique help address the overarching research problem of this study, which is: *given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?* In addition, these levels of analysis are also used to develop my theoretical and analytical framework for this study (referred to in more detail at the end of this chapter).

In the next section, Bronfenbrenner's (1979) ecological levels perspective is discussed, as a means of understanding student intervention as a process occurring within dynamically interacting layered social levels.

In his earlier models (Figure 2.1), Bronfenbrenner (1979) placed the individual (or child) at the centre, with four concentric rings radiating outwards, each representing levels of the social world which influence their behaviour or development. The first ring (microsystem) represents intrapersonal relationships with specific players (for example, families, friends, peer groups) experienced daily. The outer ring (macro level) represents social forces such as culture and social norms, but also include patterns at national and international levels shaped by economics, policy, and philosophy.

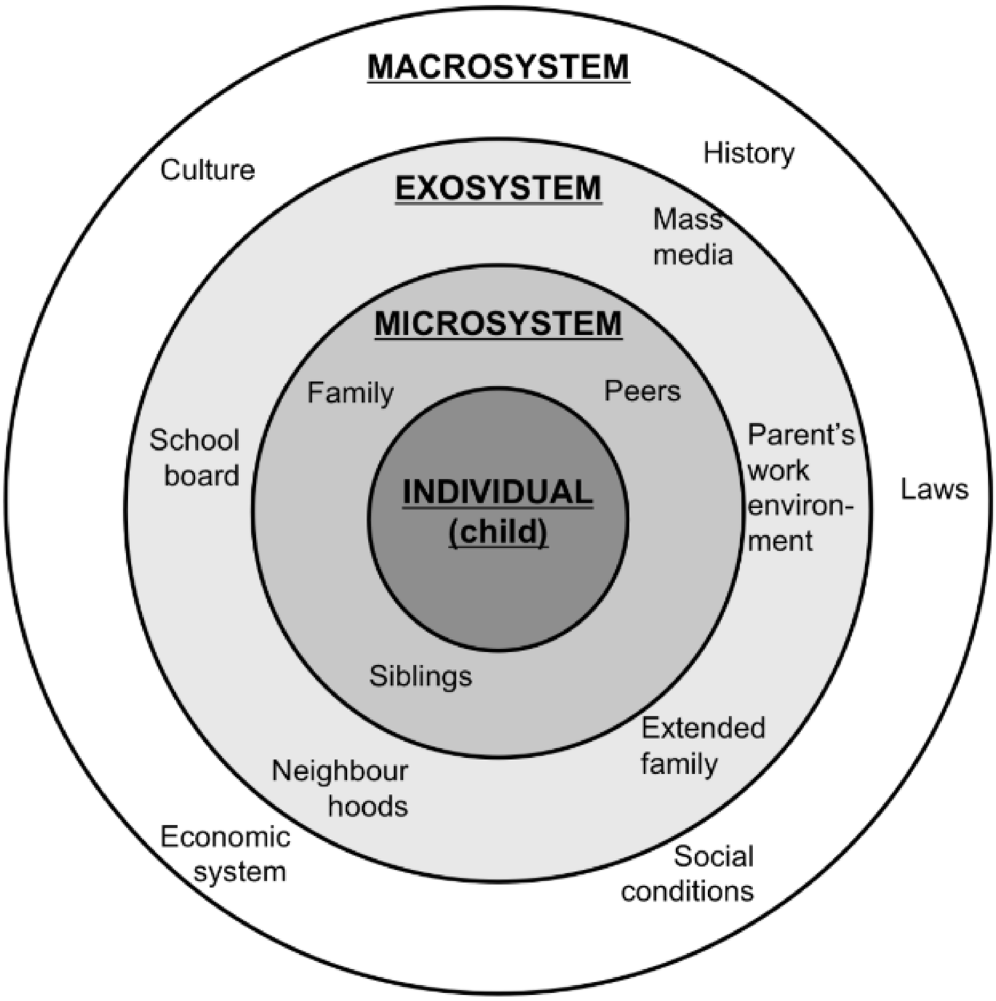


Figure 2. 1 An Adapted Diagrammatic Representation of Bronfenbrenner's (1979) Ecological Levels Model

Articulated by some as a contextually specific 'meta-concept', or a 'guiding' set of 'heuristics' rather than a testable construct or theory (Richard et al., 2011), Bronfenbrenner's conceptual model is under constant revision and development (Tudge et al., 2017) to delve into the features of teachers' professional qualities and the quality of those constructions. Such an attempt is conducive for analysing the complex interplay between teachers and the environment in which they live as well as the role of contextual factors in shaping teachers' qualities. Nevertheless, it provides a useful framework and has been adopted by fields including epidemiology (Baral et al., 2013), public health promotion (Richard et al., 2011) social policy (Ostrom, Cox, and Schlager, 2014), environmental studies (Benessaiah and Sengupta, 2014), and animal behaviour (Lu, Koenig, and Borries, 2008) indicating the relevance to how levels of influence affect an individual in many areas of life. I would suggest that implementing a similar approach of a Health Promoting School (HPS) aligns with an ecological model as it is influenced by education and social policy (*macro level*) and by social structures (*exo level*) that can shape the availability of resources to help build supportive physical and social environments (*micro level*) (Bassett-Gunters et al., 2012; Basset-Gunter et al., 2015). HPS is also a collaborative and multi-component approach that engages partners in the community (*meso level*), such as public health, recreation, non-government organizations, local business and universities. Focusing on system-level actions can ensure synergy between decisions (*macro-* and *exo level*) and operations (Denis and Lehoux, 2013) (*micro level*) which could enhance teachers' understanding of the influence on children's learning.

Figure 2.1 represents Bronfenbrenner's ecological model which offers an overall framework to consider the interrelationship among stakeholders and structures across multiple levels in schools which acknowledges that levels are nested within levels. The model allows complexity within and across the system to be displayed by showing how various structures interact and can change overtime (Lerner and Overton, 2008; Eccles and Roeser, 2011). Thus, *macro level* influences the overall systems structure, such as the international-, national policy, Socio-Economic Status (SES), time and political levels; the *exo level* constitutes other informal and formal social structures, such as pedagogical knowledge, parent's workplace, health promoting schools, subject content knowledge and neighbour or community context that influence school structures and impact student learning; *micro levels* focus on relationship between individuals and their immediate settings; and *meso levels* comprise interactions between *micro levels* (Bronfenbrenner, 1979). This approach to analysis for this study means that a HPS in the field of secondary school mathematics interventions can be accommodated within the model.

Whilst Bronfenbrenner‘s focus was developmental psychology, his work offers a useful perspective on research in education (for example, Beardsley and Harnett, 1998; Hannon, 1998) and is used to inform academic achievement (for example, Veneziano and Rohner, 1998; Nord and Brimhall, 1998; Mazza, 2002). An ecological approach is helpful for explaining and exploring the circumstances in which this research was conducted. The student interventions and teacher education occur, and is studied, within a macrosystem of institutional influences on the provision of services for the students at Majac Secondary School. This has concrete expression in an exosystem of linkages and processes between settings, which impact on the mesosystem of interactions between home and school with which the students and teachers are involved, and the microsystem of student perspectives with a specific secondary school (Bronfenbrenner, 1979; Anning and Edwards, 2006; Palaiologou, 2008). It is used as an organising framework which established The Jacobs (2020) Socio-Ecological Model for Interventions in Secondary Mathematics (SEMISM), Figure 2.2, adapted from Bronfenbrenner's (1979) ecological model; the *macro level* (Institutional Patterns); *the exo* *level* (Linkages and Processes between settings), *meso level* (Interactions Between Home and School); and the *micro level* (Student Perspectives) which provides an appropriate lens through which to view the experiences of the student participants in this study as it emphasises multiple influences that shape development in immediate and broader settings. Aligning my understanding of Bronfenbrenner's work with the context at Majac Secondary School prompted me to create a model that would enable me to better understand the complex nature of what influences teaching and learning in mathematics. The Jacobs (2020) SEMISM will be further discussed in the theoretical framework section and referred to during the analysis of data so as to both understand and act on.

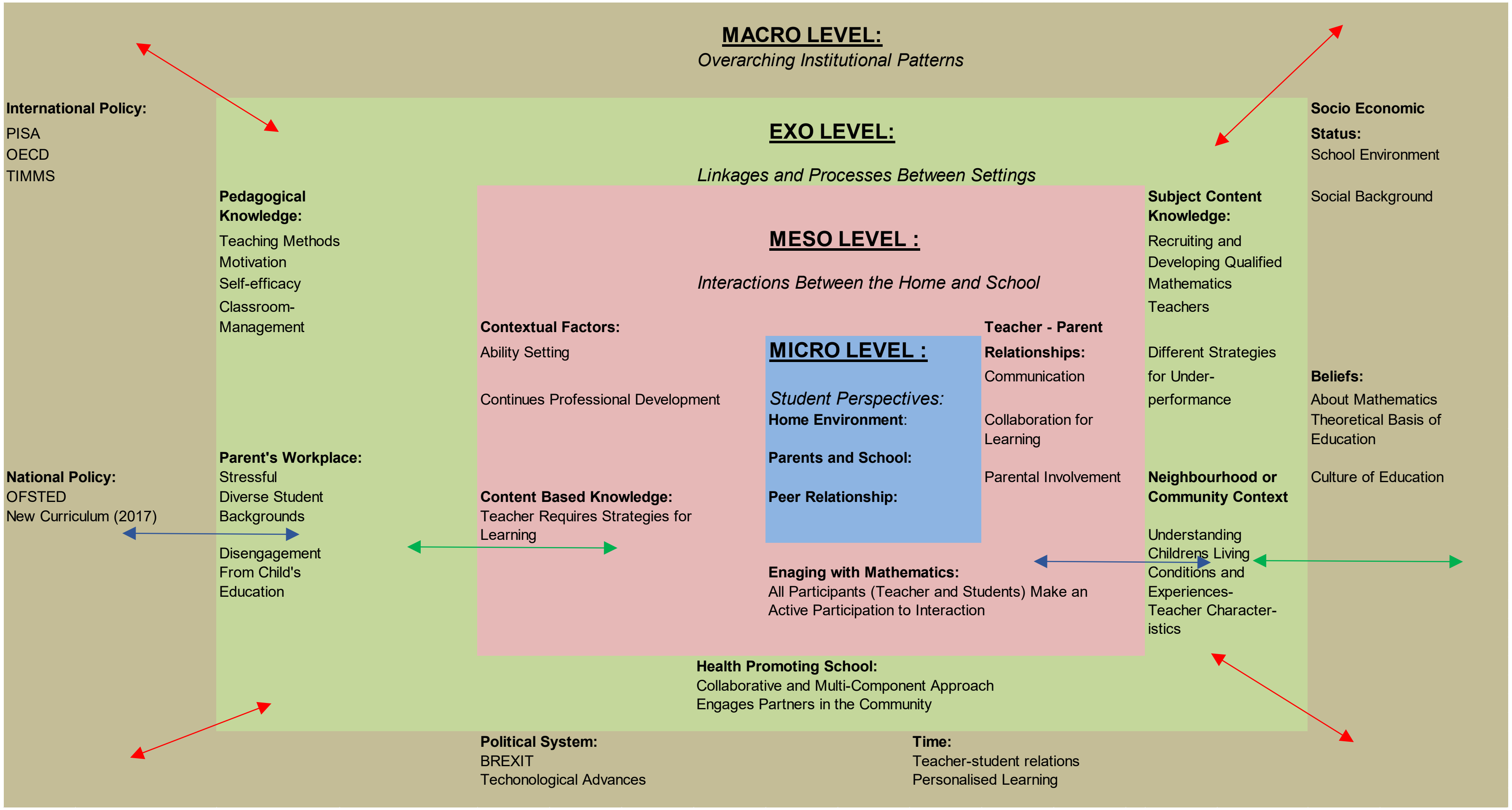


Figure 2. 2 Jacobs 2020) Socio-Ecological Model for Interventions in Secondary Mathematics (SEMISM)

Jacobs (2020) Socio- ecological model for intervention in mathematics - adopted from Bronfenbrenner's ecological model of human development. Source: "Ecological Models of Human Development," by U. Bronfenbrenner, 1994, in International Encyclopaedia of Education (pp. 37-42), Oxford, UK: Elsevier

In the next section, an overview of mathematics is provided, where the subject of mathematics is placed in context by examining the secondary school trends at an international and national level. In line with the research problem outlined in Chapter One, the aim of this section is to compare international mathematics interventions with national United Kingdom (UK), achievements in the area.

2.1 Overview of Mathematics

This section provides a critical review of the development of mathematics education in England through a brief history of the relevant developments in mathematics, continuation of GCSE mathematics; the new reformed GCSE mathematics; international and national contextual influences.

2.1.1 Historical Review of Developments in Mathematics

In education establishments before the students attend Higher Education (HE), there are many different age ranges, such as 11-18, 14-19 or 16-19 with varied focuses (Hillman, 2014) and in most these they learn mathematics. The last age range could correspond to small sixth forms attached to a school, or they could be large, stand-alone Colleges of Further Education (FE) or Sixth Form Colleges.

It is very difficult to definitively describe the way students have been taught mathematics in all these different establishments. Whether in the state or independent sector, some will have been in small classes whilst others will have been in large classes; some will have had well-qualified mathematics teachers, others non-qualified mathematics teachers. One might logically conclude, given the great diversity in provision of mathematics education across the country, that students will have had different teaching and learning experiences in relation to mathematics. General qualifications in mathematics have developed in the context of widespread, recent changes in expectations for students. The Cockcroft Report, 'Mathematics Counts' (1982) found that in 1979 about one third of school leavers took the General Certificate of Education, Ordinary Level (GCE O level) in mathematics with only one fifth of all school leavers gaining a pass grade. In 1979, well over 80% of A-level students had obtained A or B at GCE O-level mathematics and so came from the top 11% of the age cohort at 16 years old; the vast majority of the rest came from the top 20%. In 1994, the percentage of A-level students who had obtained an A or B grade at GCSE showed little change, but now the comparable figures within the age cohort were the top 17% and 40%, respectively. The large numbers of students obtaining GCSE mathematics via intermediate papers, caused A-level teachers now to deal with students drawn from a much wider range of mathematical ability and attainment (Ofsted, 1994). The replacement of GCE O level by GCSE in 1988 may be seen as the start of a process by which these 'school leaving' qualifications could more closely reflect what the majority of 16-year-olds know, understand and can do.

Students in all state-maintained schools (not academies) in England must follow the National Curriculum (NC) until age 16. A revised 'NC in England: mathematics programmes of study' document and also a 'Mathematics, GCSE subject content and assessment objectives' document were published in 2013 (DfE, 2013). The reformed GCSE mathematics, which was examined for the first time in 2017, had an increase in content and a greater emphasis on mathematical problem-solving. GCSE mathematics assesses the mathematics NC at age 16. Although the GCSE course is often thought of as a two-year course, the GCSE content in mathematics builds directly on earlier content in mathematics and therefore, the GCSE examinations test mathematics that students have learnt throughout secondary school and it is an ideal way of developing incremental, over time gains in knowledge for the individual. The content of GCSE mathematics is the same for all awarding bodies such as Assessment and Qualifications Alliance (AQA), Edexcel, Oxford, Cambridge, and RSA Examinations (OCR) and Welsh Joint Education Committee (WJEC). GCSE mathematics is a linear qualification, and all of the assessment is by examination (three written papers, from 2017), taken at the end of the course (Hodgen, Marks and Pepper, 2013). The historical aspects influence the perception of mathematics in society and how it is represented in the curriculum.

2.1.2 Continuation of GCSEs and the Reformed GCSE (2017)

Many students do not learn any more mathematics after GCSE in the UK (DfE, 2013). Following the Wolf Report (Wolf, 2011), the UK Government legislated that, from September 2013, all young people who did not achieve a grade C in mathematics and English GCSEs had to continue studying these subjects post-16 years until they secured a pass in them. Therefore, since 2014, students failing this requirement have continued to work towards achieving these qualifications, or an approved interim qualification as a 'steppingstone' towards a GCSE. For some students, reaching the GCSE standard may potentially have required progressive stepping-stones, for example, through Functional Skills qualifications, or through Foundation and Higher Free-Standing Mathematics Qualifications. According to Porter (2015), 31% of the cohort who took GCSE mathematics in the summer of 2014, did not achieve a grade C or above (just below 180,000 students in England). The reformed GCSE mathematics (2017) is graded on a nine-point scale, with nine as the highest grade, see Figure 2.3. Studying GCSEs provides a student with an essential foundation in a range of subjects. It allows the student to focus on topics of interest and gives them the chance to explore them deeper in Advanced Levels (A-levels). The GCSEs act as an educational gateway, unlocking access to higher education and further fields of study.

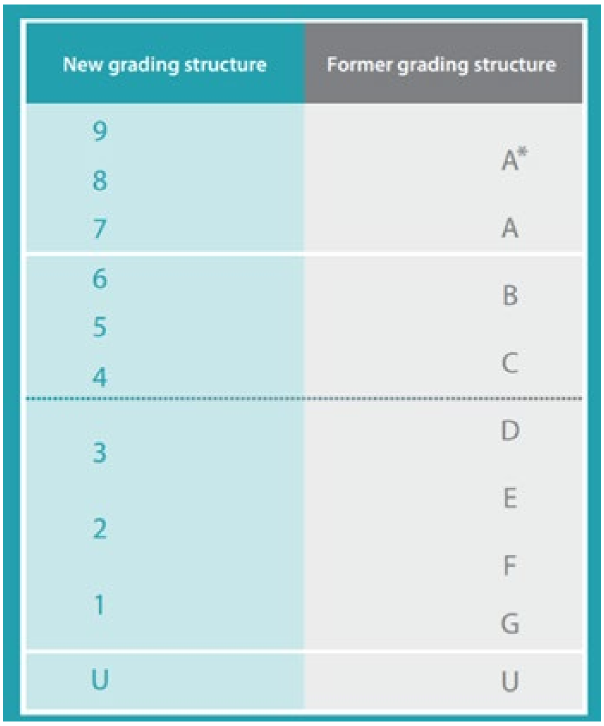


Figure 2. 3 Reformed Mathematics Grading System from 2017 (Ofqual, 2017)

Confidence in the quality of the qualification is of interest to employers and education providers so exam boards are under continued pressure to demonstrate grade equivalence regardless of the time or name of the qualification. Prior to 2017, grades were reported as letters and from 2017, grades are reported as numbers (as demonstrated in Figure 2.3). For example, a grade four in the new GCSE equates to grade C in the previous GCSE mathematics and is considered a pass grade. Grade seven in the new GCSE mathematics equated to a grade A in the previous GCSE mathematics. Grades eight and nine equated to the previous A* grade, with grade nine indicating exceptional performance. Grades one to five are available at Foundation Tier and grades four to nine are available at Higher Tier. Therefore, the changes overtime matter because the new scale recognises more clearly the achievements of high-attaining students, as the additional grades allow for greater differentiation. Changing from letters to numbers also allows anyone; for example, an employer; to see easily whether a student has taken a new, more challenging GCSE, or an old, reformed GCSE.

The content of the GCSEs in mathematics taken from summer 2017 onwards was similar to that of the previous GCSEs. The new GCSEs (from 2017) were intended to be more mathematically demanding and contained a little more material, such as inverse and composite functions and areas under graphs at Higher Tier and expanding, factorising and solving quadratics, plus simple trigonometry at Foundation Tier. The new reformed GCSE examinations (from 2017) placed more emphasis on reasoning, problem-solving and functionality in mathematics (DfE, 2013). The relevance of this study is that it investigates intervention strategies to support underachieving students at GCSE mathematics who are currently predicted to just miss out on a ‘good GCSE pass’ this study focusses on how to approach questions, such as, problem-solving in the examinations, a focus for intervention brought about by the change of emphasis within the GCSE examination.

The new qualifications were the result of a long process of reform that began in 2011 with the national curriculum review in England, involving extensive consultation with schools, Further Education Colleges (FE), Higher Education (HE) and employers on the principles of reform and subject content. These reforms were part of the UK Government's drive to improve schools', students' and employers' confidence in the qualifications, ensuring that young people have the knowledge and skills needed to go on to work and further study. The English government has said it wants to match school standards to those of the strongest performing education systems in the world, such as Hong Kong and Shanghai. High-performing school education systems in East Asia have received increased attention as numerous countries attempt to match their success. Despite widespread knowledge of their high levels of performance, comparatively little is understood of the successful reforms that led to these improvements. Reforms such as, confident school leadership is key in the development of these systems. At the heart of these reforms is a clear understanding that to improve schooling is a behavioural change process. To improve student learning is to change learning behaviours (Barber and Mourshed, 2010). To improve teaching is to change teaching behaviours (exo-level) (Pont et al., 2008). To improve school leadership (macro-level) therefore is to change school leaders' behaviours so they can lead behavioural change in schools (Caldwell, 2002). Behavioural change is the key to turning around performance. Understanding the changes required in leadership and teaching has been fundamental to the success of several high-performing education systems, particularly in East Asia (Jensen et al., 2012). To achieve these changes requires a thorough understanding of the change process and how it operates in school education. It also requires an understanding of the context in which school leaders in England operate. Change requires a clear vision that is built and reinforced through multiple mechanisms (macro, exo, meso levels). It is clear, because of the pass mark of grades 4 to 9 in mathematics by GCSE students that the current context in England can make this difficult for some school leaders (Hargreaves, 2012).

2.1.3 International Contextual Influences

In recent years, the English government's numeracy projects have been highly influenced by the Dutch research into teaching mental arithmetic: for example, bead strings and empty number lines were recommended in official guidance (Department for Children, Schools and Families (DCSF), 2003; Van de Pol, Volman and Beishuizen, 2012). However, according to Brown (2014: p.7), practical work has steadily declined, "being a victim as much of the advent of interactive white boards (IWB) and cuts in equipment budgets as of reduced teacher training periods". More recently, the English government has been influenced by high performing areas, such as Singapore. Brown (2014: p.7) points out that the Singapore curriculum is one which the UK "exported to Singapore in the 1950s, having then abandoned it ourselves as being widely dysfunctional". Current Singaporean influences in the UK, as evidenced by the government funded National Centre for Excellence in Teaching Mathematics (NCETM) include the bar model approach and the use of Singapore textbooks advocating a Brunerian concrete- pictorial- abstract approach (Fong, 2014). This model has come to be interpreted as teachers presenting examples in different modes, in a linear sequence, which neither reflects original intentions for an active curriculum nor Bruner's pedagogy, according to Hoong, Kin and Pien (2015): it is not surprising teachers are confused.

According to the National Council of Teachers of Mathematics (NCTM, 2000) the first era of the new millennium is a good time to think of the past, consider the present, and plan for the future. The past century brought changes that transformed education and, some of the most dramatic changes have come in mathematics education. Students in secondary schools require an education in mathematics that goes beyond what was needed by students in the past. At the turn of the last century, students studied arithmetic in the primary school, they completed sums or long division on slates (Morrow and Kenney, 1998) or, later, in lined paper tablets, and they memorised the times tables. Today, the third- and fourth-generation descendants of those schoolchildren log onto the internet for information about fractals and Fibonacci numbers. In class they work with manipulatives and study economic concepts such as supply and demand; they even personally interact with astronauts as they conduct experiments on space shuttles. These pedagogical developments are a significant challenge to today's mathematics teachers. In the first half of the 20th Century, curriculum development emphasised shop-and-yard skills (Morrow and Kenney, 1998). Prompted by the idea of real-life education, some teachers focused on identifying minimal competencies needed to perform different jobs: pounds-and-pennies mathematics for clerking, feet-and-inches mathematics for carpentry, and measuring-cups-and-spoons mathematics for cooks and homemakers (Morrow and Kenney, 1998). The changing needs of an ever-evolving world have made this restrictive view not only obsolete but also dangerous.

In the United States of America (US) and Germany mathematics teachers wanted to teach students a particular skill (Stigler and Herbert, 1999). In Japan, the aim was that students "understand a new concept or think in a new way" (Swan, 2006:

p.43). The 'traditional' conception of mathematics as a body of knowledge, skills, and techniques for students to acquire is prevalent in western society. Swan (2006: p.41), for example, contrasts more 'progressive' approaches where students "construct concepts and strategies through exploration or creativity and discussion". Therefore, English teachers of mathematics may be torn between the two approaches.

Mathematics knowledge and qualifications are increasingly important gateways to further and higher education, for crucial life-skills and in order to respond to economic change. Mathematics provides an effective way of building mental discipline and encourages logical reasoning and mental rigour. In addition, mathematical knowledge plays a crucial role in understanding the contents of other school subjects such as science, social studies, and even music and art. As mathematics has certain qualities that are nurtured by mathematics are power of reasoning, creativity, abstract or spatial thinking, critical thinking, problem-solving ability and even effective communication skill. All these qualities are needed in the 21st century for students to move into the workforce with qualities that they can use in their everyday life.

The research literature, national and international, outlined in this section should provide some food for thought, in some instances strengthening the case for intended reforms and in others providing new and sometimes challenging thinking. In the next section, relevant research literature about the use of national context in mathematics curricula will to be addressed.

2.1.4 National Contextual Influences

In order to answer the secondary research questions, I will discuss the contextual influences as stated in Table 2.1 below:

Table 2. 1 Contextual levels versus Research Questions

Contextual Level	Research Question
International / Comparative level (Macro Level Analysis	(1) Why do students underachieve academically when the ability to achieve is present?
National Level (Macro Level Analysis)	(2) What were the key participants' perceptions of their successes and failures in the study?
Institutional Level (Meso Level Analysis)	(3) What factors contribute to their psychological and academic needs?
Individual Student Level (Micro Level Analysis)	(4) Why is it important to empower able underachievers? (5) How can strategies and techniques help enhance student performance?

This section reviews the issues relating to secondary mathematics with the aim of identifying interventions that will support students in Majac Secondary School.

The student participants in this study were chosen from all the ability mathematics sets and some of them were just missing out on a B or A-grade and needed support to secure that grade to undertake mathematics in their further studies. Intervening with students at secondary school would support their transition from secondary school into further, higher and the workforce. This study took place at an interesting time in secondary mathematics education in England. At the inception of data collection, schools were beginning to work through the introduction of a new National Curriculum aimed at raising the mathematical attainment of children in England (DfE, 2014). Recent research has identified that 40% of students do not achieve a GCSE C grade or above in mathematics by the age of 16 (DfE, 2014). At that time (2014), 90% of those who do not achieve a C in mathematics by 16 do not achieve it by 19 (DfE, 2014). The 2016 GCSE mathematics results identified the greatest decline since the exams were launched in 1988 (Coughlin, 2010). The number of students gaining A*-C grades decreased by 2.1% to 66.9% (Robertson, 2016). This decline was a result of a recent reform in the education system, the first of which demands that students aged 16-19, who do not hold a GCSE at A*-C in mathematics, continue learning mathematics as part of their study programme (Wolf, 2011). The student participants in the study were about to become the first cohort assessed against this new curriculum under the new testing arrangements (Gibb, 2015). This made it a particularly important time to look behind the statistics of international, national, and local performance and the rhetoric surrounding the introduction of a new curriculum.

Hogden and Marks (2013: p.1) stated that "[m]athematics is a critical skill for all", including to those who have not achieved a Grade C or 4 at GCSE by age 16. There is some validity in the observation given the monitoring of both national and international comparison data, particularly in terms of technological change, the demand for mathematical skills is increasing (Vorderman, et al., 2011; Brynjolfsson and McAfee, 2014). Technological changes to support mathematics achievement, will be discussed in more detail later in the study.

Mathematics is also important even for non-Science, Technology, Engineering and Mathematics (STEM) subjects at university (Advisory Committee on Mathematics Education (ACME), 2010; Porkess, 2012). The main arguments for the importance of mathematics, fall into three areas: mathematics is a core skill for all adults in life generally; a mathematically well-educated population will contribute to the country's economic prosperity; and mathematics is important for its own sake (Norris, 2012; Porkess, 2012).

The importance of the need for all citizens to understand data and view statistics critically is strongly made (Porkess, 2012). The argument is that increasingly the debate in society rests on literacy, particularly with increasing amounts of data within a digital society, and an understanding of these arguments is necessary for informed debate and decision making (Vorder man et al., 2011; Porkess, 2012). For example, the British Academy (2012: p.7) stated that without statistical understanding citizens, voters and consumers cannot play a full part. To call politicians, media and business to account, we need the skills to know when spurious arguments are being advanced.

There seems to be little doubt that mathematical skills are increasingly needed in the workplace. Graduates with quantitative skills are important in a very wide range of jobs (Vorderman et al., 2011; Norris, 2012; Hodgen and Marks, 2013). However, importantly, "people in the workplace need to be able to make sense of the mathematics they are using if they are to avoid making mistakes in the workplace" (Hodgen and Marks, 2013: p.1). Therefore, the need for mathematics in an individual's jobs prospects is important, but clearly creating and filling these jobs also contributes to the country's economic prosperity.

For the UK to remain competitive in the world economy research (Ofsted, 2011; Whitehouse and Burdett, 2013) suggested, "mathematics is key for economic development and for technical progress" (ACME, 2010: p.4). Archer, Osborne, and DeWitt (2012: p.1) stated, "the foundation of future economic success" rests on the importance of science and mathematics and the key role to be played by Science, Technology, Engineering and Mathematics (STEM) in driving innovation, growth and economic recovery. Therefore, it seemed that driving innovation and growth relies on cutting-edge research and ambitious business and industry. To meet the global ambitions of a knowledge-based economy the quality and size of the pool of young people engaged in mainstream mathematics and science education is important (Royal Society, 2011). Vorderman et al (2011) stated that mathematical skills underpin the attributes such as problem-solving which are of critical importance within modern environments, such as the pharmaceutical industry. Therefore, secondary schools need to ensure that students have a good grounding in mathematics which will equip them for their future lives by developing the skills valued in industry and university.

The current National Curriculum (NC) examinations incorporate some assessment of using and applying mathematics, yet Ofsted (2012) reported that in most classrooms, unsurprisingly, the emphasis is on 'teaching to the test' with very little using and applying mathematics. Ofsted (2012) also reports that students unlikely to meet the government target are seriously neglected and tend to get an impoverished experience of mathematics. This situation is likely to be exacerbated with the expectations set out in the proposals, especially the heavy emphasis on procedures. Many students will be labelled as failures and the current culture of it being acceptable to be 'bad' at mathematics would be perpetuated.

We (teachers/educators) should not accept a mid-20th century approach to teaching mathematics as this will not empower students to achieve their very best in the 21st century, high-technology, data-rich world. Therefore, teachers of mathematics need to view the subject as an interesting, useful and creative subject, with many interconnections and links with other subjects and to real life through which students develop an enthusiasm and curiosity for learning mathematics and using that knowledge to solve problems in the widest sense. This view is not restricted to a small clique of teachers but is commonly found across the mathematics teaching profession in the UK and abroad (Renninger and Hidi, 2016) (for example, Poland and the Netherlands). The next section discusses the development of mathematics education in the UK.

2.1.5 Summary of Overview of Mathematics

We live in a time of extraordinary and accelerating change. New knowledge, tools and ways of doing and communicating mathematics continue to emerge and evolve. The need to understand and be able to use mathematics in everyday life and in the workplace has never been greater and will continue to increase. In this changing world, those who understand, and can do mathematics are likely have significantly enhanced opportunities and options for shaping their futures. Mathematical competence opens doors to productive futures. A lack of mathematical competence keeps those doors closed (NCTM, 2000). The National Council of Teachers of

Mathematics (NCTM, 2000) challenges the notion that mathematics is for only the select few and I would agree that everyone needs to understand mathematics. All students should have the opportunity and the support necessary to learn mathematics with depth and understanding.

Mathematics teaching has undergone many reforms in recent decades. Much of the reforms have originated as a result of advancements in the fields of cognitive psychology, mathematics, and mathematics education (Raizen, 1997; NCTM, 2000; Begg, 2003). The changes have been particularly significant in the areas of mathematical curricula and instructional strategies, including the use of technology in teaching and learning mathematics. The above-mentioned changes have led mathematics teachers to re-look at the overall goals of mathematics teaching with particular emphasis to active student involvement in an enquiry-based learning as opposed to the expository style of teaching used traditionally.

The following section examines the relevant literature about teacher knowledge in mathematics education.

2.2 Teaching Mathematics

How mathematics is taught was of great importance to this study because if we are to critique why students are failing to achieve, then we need to look at how they are taught. The knowledge an effective teacher possesses has been and is still an important focus for educational research; however, the distinctions between different bodies of knowledge and the vocabulary used to describe them vary significantly. For example, Shulman (1986) breaks teacher knowledge into three categories: content knowledge, pedagogical content knowledge, and curriculum knowledge. Grossman

(1990) have divided teachers' knowledge into four domains including subject-matter knowledge, general pedagogical knowledge, pedagogical content knowledge, and knowledge of context. Teachers' conceptual understanding and knowledge is critically important at any level, and it supported me in this study to develop the flexibility for recognizing opportunities that I can use for moving students' understandings forward. When I use my knowledge to enhance student learning, I am engaging in effective practice which can develop student learning further. In the next section, I will consider teacher knowledge through the domains and the forms of teacher knowledge.

2.2.1 Teacher Knowledge

Verloop, Van Driel and Meijer (2001: p.446) suggested that the term "teacher knowledge" refers to "the whole of the knowledge and insights that underlie teacher's actions in practice". This is quite a dated but useful definition and I am adopting it for use in this study because the notion of teacher knowledge is an overarching concept that includes the codified or codifiable aggregation of conceptions and knowledge of disciplines, understanding and beliefs of school education and student learning, skills of organisation, communication and presentation, and intuitions of context that are all inextricably intertwined in the mind of a teacher (Shulman, 1987; Verloop et al., 2001). Teachers have been said to gain such knowledge from four different sources: knowledge in content disciplines, educational materials and structures, formal educational scholarly literature, and the wisdom of practice (Shulman, 1987). Thus, teacher knowledge can be seen as a combination or amalgam of the knowledge that they acquire from their daily practical teaching experience, the knowledge that they acquired from formal teacher education program or continued professional training, and any specific disciplinary training (Verloop et al., 2001). Teacher knowledge has the properties of both individuality and conformity: on one hand, teacher knowledge is unique to the individual teacher and confined by the specific content and context. On the other hand, teacher knowledge has common, shared or consensual components. In any case, teacher knowledge is purposed for direct application within teaching practice and encompasses many tacit forms (Verloop et al., 2001). I could argue that teachers need such complex forms of knowledge to inform their instructional decisions, both in their planning of lessons prior to and in the enactments of their teaching that may occur 'on-the-fly'.

Domains of Teacher Knowledge

The domains of teacher knowledge are valuable in highlighting areas in which teachers may need to have knowledge. Researchers (for example, Ball, Thames and Phelps, 2008; Rowland, et al., 2009; O'Meara, 2011; Baumert and Kunter, 2013) have suggested different domains of teacher knowledge which supported the process of categorizing practising teachers' views which I will use to develop my theoretical framework. The theoretical framework appeared to be promising for categorizing these views, since it has previously worked relatively well in classifying teacher knowledge (Markworth, Goodwin, and Glisson, 2009; Fauskanger, et al., 2012). Furthermore, Shulman (1987) identified seven categories of teacher knowledge: content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of students and their characteristics, knowledge of educational contexts, and the knowledge of the philosophical and historical aims of education. This seems like a long list, compared to Verloop, Van Driel and Meijer (2001) definition but researchers (Coe et al., 2014) have agreed that teachers need strong subject knowledge, and Carrell, Page, and West, (2010) seem to share the view that mathematics teachers also need a different kind of knowledge from that required by mathematicians which some of them may have aimed to be while undertaking their undergraduate mathematics degrees. Carrell et al (2010) consider that pedagogical knowledge is needed in the teaching of mathematics.

One of the biggest dilemmas in educational development today is the teacher quality 'mystery': While there is clear evidence that teacher quality is a key determinant of student learning, little is known about which specific observable characteristics of teachers can account for this impact (for example, Rockoff 2004; Rivkin, Hanushek, and Kain 2005; Aaronson, Barrow, and Sander 2007). In particular, there is little evidence that those characteristics most often used in hiring and salary decisions, namely teachers' education and experience, are crucial for teacher quality. Virtually the only attribute that has been shown to be more frequently significantly correlated with student achievement is teachers' academic skills measured by scores on achievement tests (Wayne and Youngs 2003; Eide, Goldhaber, and Brewer 2004; Hanushek and Rivkin, 2006). The problem with the latter evidence, however, is that issues of omitted variables and non-random selection are very hard to address when estimating causal effects of teacher characteristics. It is clear that teachers need diverse knowledge sets, so in light of this thesis, I will address those forms of teacher mathematics knowledge that research (Frost, 2013; Putnam, 2015) has shown to have a noted effect on student achievement.

Content Knowledge

Content knowledge is an academic construct that represents an intriguing idea because it is an idea rooted in the belief that teaching requires considerably more than delivering subject content knowledge to students, and that student learning is considerably more than absorbing information for later accurate regurgitation. Content Knowledge is the knowledge that teachers develop over time, and through experience, about how to teach particular content in particular ways in order to lead to enhanced student understanding. However, Content Knowledge is not a single entity that is the same for all teachers of a given subject area; it is a particular expertise with individual idiosyncrasies and important differences that are influenced by (at least) the teaching context, content, and experience. It may be the same (or similar) for some teachers and different for others, but it is, nevertheless, a corner stone of teachers' professional knowledge and expertise that supports students' learning and achievement.

Content Knowledge is the "knowledge, understanding, skill, and disposition that are to be learned by school children" (Shulman, 1987: p. 9). This form of knowledge includes three levels of understanding: (a) the major facts, concepts, terms, principles, and procedures within a subject area; (b) the structure and organisation within that subject; and (c) how scientific works are conducted, evaluated, and accepted in that subject (Schwab, 1964; Carlsen, 1999; Gess-Newsome et al., 2017). Teachers acquire content knowledge from their formal university studies, textbook, personal reflection and learning of subject principles, their practical teaching experiences, and related social movement (Tynjälä, 2008; Werquin, 2010). A teacher's content knowledge would likely affect what kinds of activities he or she would undertake or what topics would be addressed within the classroom. For example, in a review of studies about the influences of content knowledge on teaching practice, Gess-Newsome et al (2017) concluded that teachers with a lower level of conceptual knowledge of their subject tended to teach isolated and fact-based knowledge rather than promoting students' conceptual understanding. Furthermore, teachers with sophisticated understanding of the structure and nature of subject matter were more able to connect students' out-of-school experience to school-based instruction; they were likely to teach students how human knowledge is generated and evaluated as well as the idea that mathematics is a way to understand the real-life world. During the focus group interviews students stated that some teachers at times *could not even answer their mathematics related questions in the classroom* as they (the teachers) did not have the knowledge on how to approach the question or how to explain to the student how to get to the answer. What mathematics teachers need to know for teaching is a contentious issue in mathematics education because it may be seen as a tall order to prescribe the content knowledge beyond what is in the National Curriculum that would enable a teacher to teach 'effectively' in a school classroom.

Content knowledge also influences the instructional strategies and materials that teachers select in their classroom teaching and their planning of lessons. For example, broad guidelines, to show how teachers can play a significant role in developing their perspectives on learning, teaching, and the nature of mathematics, which could in turn, influence their knowledge, beliefs, and instructional practice, have been provided by the NCTM (2000: p.19) about some of the things that teachers might do to enhance effective classroom discourse: "Effective teaching involves observing students [and] listening carefully to their ideas and explanations". These guidelines could be used as a starting point to report on the features of effective pedagogy that are specific to classroom discourse in mathematics classrooms. When asking students questions, the teachers asked relatively more cognitively high-level questions when they were teaching high-level knowledge topics. For example, Teacher DMvT stated during her observation: '*What can you suggest about the sides of the parallelogram?' What can you point out about sides of the shape? What evidence in the question can you find that supports your solution?'* When planning instruction about topics that they knew well, the teachers planned more whole-class interactions, to teach new materials or review student work. Teachers planned student group activities and lecturing most often when they did not know the topics well, and their plans were not clear in terms of what the students should be doing in their groups. However, while essential for learning, superior content knowledge alone is not sufficient to ensure effective inquiry teaching (Hollon et al., 1991). Other domains of teacher knowledge contribute to the successful implementation of inquiry or other innovative approaches.

Pedagogical Knowledge

Pedagogical knowledge refers to the specialised knowledge of teachers for creating effective teaching and learning environments for all students and it is the domain of knowledge about classroom management, available instructional strategies, and student learning which is independent of specific subject matter domains (König, et al., 2011; Voss, Kunter, and Baumert, 2011). It is the basis of the conscious activities in which teachers engage in their classroom for the purpose of enhancing students' learning (Gess-Newsome et al., 2017). Davis (2009) observed that teachers can acquire pedagogical knowledge from three sources: their personal beliefs and perceptions of teaching and learning based on their experiences as students, the research and scholarly literature that presented to them in teacher preparation programs, and the practical experience working in real classroom during their pre-service student teaching and the early year of professional practice. Other researchers (Loughran, Mulhall and Berry, 2004; 2008 and 2012) have synthesized pedagogical knowledge into four components of strategies and arrangements for effective teaching: classroom management, instructional strategies, classroom discourse, and understanding and beliefs about students, learning, and teaching. Knowledge of classroom management enables teachers to establish classroom norms (rules and procedures), manage learning groups, monitor and organise classroom events, and respond to students' behaviour. Teachers will thus be able to establish and maintain the order of the classroom and keep students highly engaged (Clunies-Ross, Little and Kienhuis, 2008; McDonald, 2013) an important observation from the focus group participants in this study.

Teachers' classroom management skills have a critical impact on student achievement (Kayikci, 2009; Iacob and Musuroi, 2013). Even though it was difficult to find recent studies that compare the effects of different levels of classroom management knowledge on teachers' teaching practice, specific classroom management skills that can result in better students' achievement have been identified in Table 2.2.

Table 2. 2 Classroom management skills

Researchers	Classroom organisation and management behaviour
Morine-Dershimer and Kent (1999)	(a) spending more time focusing on content, (b) organising learning activities that match the students' level, (c) maintaining momentum in instruction, (d) structuring the materials properly, presenting information clearly, and (e) giving students adequate wait-time to respond.
Emmer and Evertson (1981)	(a) introducing classroom management system at the beginning of the school year and implementing it consistently throughout the year, (b) letting students work in small group rather than in whole class, and (c) providing more academic feedback and substantive interaction.

Both Chandler and Kapelner (2010) and Qureshi et al (2013) noticed the effectiveness of extrinsic rewards and incentive system. Externally motivating strategies, by their very nature, are, of course, very prominent in the classroom, as students are required to be aware of the consequences of their actions, be they good or bad. However, in my observations during the after-school intervention lessons, I noticed a rather more subtle system of psychologically motivating factors at play. For example, in one of the lessons relating to algebra, Ms Hanekom, the teacher, rather than reacting negatively to a student giving the wrong answer to a question, remained positive and turned the situation into a learning opportunity, explaining the correct answer and reassuring the student, “It’s alright, it’s about building our skills up”. By responding in this manner, students are freed from a perceived stigma surrounding getting an answer ‘wrong’, instead gaining the understanding that errors are a chance to increase our learning and taking the fear out of giving an incorrect answer. In this subtle way, as Dweck (2012) would advocate, students are being helped, potentially, to develop more of a Growth Mindset, taking away the anxiety of looking ‘bad’ when getting something wrong and gaining the confidence to 'have a go', both in terms of responding to a verbal question and in the completion of practical performance tasks.

A knowledge of instructional strategies provides teachers a repertoire of methods or routines to structure classroom activities, interact with students, ensure students' participation and engagement, keep lessons running smoothly, promote active cognitive processing of academic content, foster understanding, and assess students' thinking (Borko and Putnam, 1997). This was clear from the after-school lesson observations success criteria needs to be prominently displayed from the start of the task, detailing the exact elements the teacher was looking for in a successful, effective performance, allowing students to recognise what they needed to do in order to achieve excellence and providing those with a Growth Mindset the opportunity to challenge themselves to achieve the best possible results. Studies by Morine-Dershimer and Kent, (1999) indicate that different instructional models can address different learning goals (developing capabilities of collaboration versus developing capabilities of self-correction) and learning tasks (well-structured tasks versus less structured task). It is reasonable to believe that teachers who have rich knowledge of possible alternative instructional strategies can use appropriate teaching methods in accordance with desired learning goals and tasks (Sng Bee, 2012). Students in the focus groups clearly identified different aspects of such behaviour.

Teachers' knowledge of classroom communication patterns can also foster positive learning outcomes (Sng Bee, 2012). Students can achieve better results and participate more actively when they are able to understand the rules and expectations expressed by the teacher, and when classroom communication matches their home communication patterns. Teachers may misinterpret students' abilities if they do not know about cultural differences between their students' communication patterns and their own. For example, in many countries around the world students from a multitude of cultural backgrounds interact daily in a variety of personal contexts. Knowledge of students, learning, and teaching denotes the "understanding and beliefs about how children think and learn, and about how teachers can foster that learning" (Borko and Putnam, 199&, p. 676). This type of knowledge also includes an understanding of the goals and values of education as well as the understanding of students' general learning ability at certain stage (age) of schooling.

With improved research findings (Felder, 2010; Nguyen et al., 2017; Tharayil et al., 2018) about student learning, my understanding of what teachers should know about student learning also shifts; from considering students as passive receivers of knowledge transmitted by teachers to thinking about them as active problem solvers and knowledge constructors (Borko and Putnam, 1997). Roehrig and Kruse (2005) inspected the relationship between teachers' beliefs about teaching and learning and their classroom practices and implementation of reform-based curriculum study. In general, teachers who held traditional beliefs about teaching and learning made small changes in their teaching practice when compared between their implementation of non-reform-based curriculum and their implementation of reform-based curriculum. In the conclusion of their study, Roehrig and Kruse (2005) believed that content knowledge was also an important factor in classroom practices, which is in resonance with Morine-Dershimer and Kent (1999)'s claim that general pedagogical knowledge must be adapted to fit the particular content and contexts. It is evident from the literature and my experiences as a researching professional, that both content and pedagogical knowledge are essential for teaching. However, merely having deep and rich knowledge in either of these two discrete domains is most likely not enough for teaching. Teachers also require knowledge in a domain called pedagogical content knowledge that enables them to better present content knowledge to their students (Shulman, 1986; 1987; Carter, 1990).

Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK) is a domain of knowledge that blends "content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of students, and represented for instruction" (Shulman, 1987: p. 8). Pedagogical content knowledge is about how teachers can transform their understanding of subject content into classroom instruction to help students learn the subject content; it is the knowledge about how to use the most appropriate analogies, illustrations, examples, explanations, and demonstrations to reorganize, represent, and formulate the subject content so that students can grasp it. During the first focus group interviews the students stated that they should have *more interactive lessons*, add *more situations*, for example t*o find the area of the rectangle*. These interactive lessons are something that they (the students) can *relate to* and furthermore they do *not just* want *textbook work* they would like to *use software on the computer or something different, rather than just do textbook*. It would seem, therefore, that teachers need pedagogical content knowledge to understand students' learning within the specific context. The relevance of the use of technology to this discussion will be addressed later in this chapter.

In the effort to conceptualize pedagogical content knowledge several researchers have tried to identify its constituent components and Park and Oliver (2008) postulated six which I have selected because they play an important role in classroom instructions. In the teaching and learning process, a PCK involves teachers' competence in delivering the conceptual approach, relational understanding and adaptive reasoning of the subject matter:

- orientations to the teaching of subject matter;
- knowledge of students' understanding;
- knowledge of curriculum;
- knowledge of instructional strategies;
- knowledge of assessment of students' learning of subject matter; and,
- teacher efficacy.

Orientations to the teaching of subject matter are teachers' overarching concepts of the purposes and goals for teaching a subject at different grade level (Grossman, 1990). Teaching orientations influence teachers' instructional decisions about setting classroom objectives, use of instructional strategies, selection of textbooks and curricular materials, and the evaluation of students (Borko and Putnam, 1997). Teaching orientations play a central role in decision-making when teachers plan, enact, and reflect upon teaching. Teachers with different teaching orientations employ different instructional strategies for different learning purposes (McConnell, 2002). Teachers may hold multiple orientations that are incompatible with the goals for teaching a subject matter (Abd-El-Khalick and Lederman, 2000). Teachers need to know what prior knowledge is required for the topics they are teaching (Ambrose et al., 2010). Students have different levels of development, ability and skill, and different approaches to learning a subject topic which was clearly identified in this study. Teachers need to be aware that a specific content representation may be understood by some students but not by others, because of students' differences (Hart, Alston and Murata, 2011). Every subject has some abstract concepts that contrast to or have no connection to students' daily experiences. Students often make errors when they do not have problem solving skills in the subject area they are learning. For example, in the focus group interviews students stated that teachers ought to know challenging topics and students' common mistakes in order to respond to them effectively.

Knowledge of instructional strategies includes the knowledge of subject-specific strategies and the knowledge of topic-specific strategies. The knowledge of topic specific representational strategies is the knowledge of how to explain specific topic concepts or principles using illustrations, examples, models, or analogies (Park and Oliver, 2008). Teachers should also know the strengths and weaknesses of the illustrations, examples, models, or analogies they may use in their explanation. Teachers' ability to invent new representations is another element of topic specific representation. The knowledge of topic-specific activity strategies is teachers' knowledge of learning activities (and their conceptual power) that can help students learn specific concepts or principles, such as problem-solving activities, demonstrations, simulations, investigations, field trips, or others (Magnusson et al., 1999; Park and Oliver, 2008).

The teacher is one of the factors that influence student achievement. Content knowledge, pedagogic content knowledge, and self-efficacy owned by teachers will characterise their performance. Content knowledge is the teacher's understanding of learning and knowledge material with other material related to what is taught.

Pedagogic content knowledge teacher deals with an understanding of the concept of errors made by the students, understand the reasons students do misconceptions, create student solutions to change students' misconceptions, and ask the right questions to correct student misconceptions. The teacher's self-efficacy (which will be discussed below in more detail) is the teacher's self-confidence in his ability to plan, implement, and assess learning in order to achieve the expected competencies or students' motivation. The higher the self-efficacy of a teacher, the higher the motivational level of the students would be. Furthermore, teacher self-efficacy has a positive impact on students' behaviour, learning and achievement.

Based on these findings represented above, it is recommended (Ball et al., 2008; Baumert et al., 2010) to continuously improve content knowledge and pedagogical content knowledge for teachers because they have a direct or indirect impact on student achievement.

Teacher Efficacy

Teacher self-efficacy is an integral part of the success that a teacher will have in the areas of instructional, classroom management and efficacy for student engagement. There is a developed belief (a stimuli received as trusted information and stored in the memory) in the association between teacher self-efficacy and high student achievement and the implementation of positive instructional techniques. Bandura (1997) proposed that because self-efficacy beliefs were clearly guided by a teacher's own inner nature and directed toward perceived abilities given specific tasks, they were powerful predictors of behaviour. There are several factors that many

(DfE, 2012; Mavhundutse, 2014; Tshabalala, 2014) would say contribute to the effectiveness of a teacher such as: (a) planning, (b) organisation, (c) content knowledge, and (d) previous experience. But none of these factors impact student success as much as teacher self-efficacy (Mojavezi and Tamiz, 2012; Gul, 2014). The evidence supports the ideas that teachers who leave teaching have lower teacher self-efficacy scores than those who remain in teaching (Glickman and Tamashiro, 1982; Burley, et al., 1991). Gregoire (2003) suggests that even when teachers understand that a given method may be more effective, their efficacy beliefs for enacting the new method will drive their implementation decisions. An individual's belief in oneself to make a difference increases the chances of actually turning the belief into action. What we come to believe about our product is what we will produce. In the eyes of teachers, how much they believe that they will make a positive difference will be evident in the success of their students. If teachers are to have high-achieving students, then it is necessary for teachers to have high achieving goals for themselves. The journey to teach students must begin first with the teacher's journey in believing that he or she can fulfill the obligation (teacher self-efficacy). Students of efficacious teachers generally have outperformed students in other classes.

Park and Oliver's study (2008) is meaningful to my study because it is a deep study of experienced secondary teachers which matches one of the lenses of my study. Self-efficacy is teachers' beliefs about their ability to carry out effective teaching methods to achieve specific teaching goals. In other words, teacher efficacy is related to their confidence in their own teaching capability. Teacher efficacy plays an important role in their identification of students' learning difficulties or misconceptions and their selection of teaching strategies. As the assistant headteacher, Raising Achievement, at Majac Secondary School, in conjunction with my role as researching professional, it was my responsibility to observe teachers in lessons and the focus was on effective GCSE teaching to increase achievement and performance was one of underachieving students. Providing feedback to teachers after the observations increased teacher efficacy when successful teaching was identified.

The development of pedagogical content knowledge is reported to be influenced by the interaction of content knowledge and pedagogical knowledge (Magnusson et al., 1999; Hashweh, 2005). Deep knowledge in a content domain is not in itself sufficient for the development of pedagogical content knowledge (Hashweh, 2005). Moreover, knowledge in different content domains may influence the development of pedagogical content knowledge unequally, according to the nature of the domains or the quality of knowledge in each domain. Therefore, teachers develop pedagogical content knowledge via different routes and across multiple pathways (Magnusson et al., 1999). For example, teachers' reflections about their teaching practices can allow for what Shulman (1987) termed 'wisdom of practice' providing an important pathway for developing pedagogical content knowledge (Hashweh, 2005; Park and Oliver, 2008). Teachers' reflections include both 'reflection-in-action' and 'reflection-on-action' (Schon, 1983, 1987, 1991; Park and Oliver, 2008). Reflection-in-action is teachers' real-time reactions to unexpected challenging moment in their enacting of a specific lesson. In this case, teachers develop new pedagogical content knowledge dynamically through integrating the knowledge they already have to address the challenge. Ms Hanekom developed her pedagogical content knowledge through engaging in after-school sessions with me as she undertook one of the sessions and we discussed the session afterwards.

Interactions with students can also impact the development of pedagogical content knowledge (Park and Oliver, 2008), as their challenging questions can push on the boundaries of teachers' content knowledge and provide enhanced opportunities to develop pedagogical content knowledge. As an example, from this study through the discussions and engagement with students at the camp Ms Hanekom and I listened to student responses, such as their enjoyment, nonverbal reactions, and evidence of learning which motivated us to expand, enriched, and validated our pedagogical content knowledge; our development of new instructional ideas; and the students' misconceptions impacted our planning of follow-on sessions. In summary, pedagogical content knowledge development is closely intertwined with teaching practices, as teachers develop pedagogical content knowledge through their teaching practice and their reflections about practice.

Technological Pedagogical Content Knowledge

Technology can be used to support many high-level education goals: increasing student learning, making school engaging and relevant, providing equitable access for disadvantaged populations, communicating between school and community to support students, supporting teachers' professional growth, and holding schools accountable for student outcomes (Zucker, 2008). The National Curriculum (NC) (DfE, 2013) for GCSE mathematics emphases the use of estimating answers, checking calculations using approximation and estimation, including answers obtained using technology. The NC aims at developing in the student the ability and willingness (Lockwood, et al., 2007; Hattie, 2011) to perform investigations using various mathematical ideas and operations. The NC for mathematics places an emphasis on Information and Communication Technology (ICT) as a tool for teaching mathematics (DfE, 2013). ICT is therefore, designed to meet expected standards of mathematics in the UK. Pellegrino and Hilton (2012) states that the National Education Technology Plan (NETP, 2010: p. ix) calls for revolutionary transformation of an education system through the use of technology, stating:

> we must leverage it to provide engaging and powerful learning experiences, content, and resources and assessments that measure student achievement in more complete, authentic, and meaningful ways. Technology-based learning and assessment systems will be pivotal in improving student learning and generating data that can be used to continuously improve the education system at all levels.

Technology is a broad term, chosen because the specific tools are changing all the time. However, for most purposes, the technologies in question are digital, most often computer based. Right now, digital images allow source materials to cross boundaries of time and space; immediate feedback allows students to practice the skills they need; creativity tools allow students to translate their understanding of concepts into a variety of media; social networks and other publishing resources allow students to not only consume, but to contribute content; simulations and games allow students to test hypotheses and explore high-consequence scenarios in a low-risk environment. Using ICT as a tool, students spend productive time developing strategies for solving complex problems and develop a deep understanding of the various mathematics topics. Students can use ICT as a tool to perform calculations, draw graphs, and help solve problems. Therefore, in this study the use of ICT was used in the intervention lessons to support students' achievement in GCSE mathematics.

Technological pedagogical content knowledge (TPCK) is the knowledge that teachers need to properly integrate technologies to facilitate and scaffold–students' learning within a particular content domain. It is a unique form of knowledge, extended from (and distinct from) Shulman's idea of pedagogical content knowledge (Angeli and Valanides, 2009; Niess, 2011). TPCK is the result of the complex interplay of three domains of foundational knowledge; content, pedagogical, and technology knowledge; within a particular context (Mishra and Koehler, 2006; Harris, Mishra, and Koehler, 2009). TPCK provides a conceptual framework for teacher knowledge about effective integration of technology within a content domain (Koehler and Mishra, 2008). TPCK is relevant to this study as the use of technology influence teachers' practices in reform-oriented ways and improve students' learning. Some teachers find new technologies difficult, disruptive, or simply undesirable in their teaching (Norton, McRobbie and Cooper, 2000; Zhao and Cziko, 2001). By having a positive impact on engagement, achievement, and confidence, technology must be successfully integrated into instruction in effective, authentic, and nonroutine ways. Ensuring technology's proper use in educational settings requires the development and understanding of the characteristics of teachers' technological pedagogical content knowledge base (Palak and Walls, 2009).

Niess (2005) and Mishra and Koehler (2006) described the following components of TPCK. The first component is teachers' overarching understanding of the purpose of incorporating technologies in students learning within a particular subject domain. The second component is teachers' awareness of how technologies can be used to detect students' prior knowledge, facilitate students' learning of difficult concepts, scaffold students' developing of new knowledge, or support students' strengthening of prior knowledge in a particular subject domain. Teachers' knowing of technology-enhanced curriculum materials in a particular subject is the third component of TPCK. Teachers' repositories of instructional strategies of using technology to represent concept and to support students learning in constructive ways is the fourth TPCK component. In addition, it would seem that teachers' knowing of creating new technology enhanced learning materials or learning environment for a specific subject domain should also be considered as a component of TPCK. The students stated in the focus group interviews that they would appreciate more active, hands-on engaged lessons which involved technology, instead of textbook use.

The development of TPCK is often a process that has multiple stages. For example, Niess, Sadri, and Lee (2007) identified five stages of development in a study about mathematics teachers' learning to integrate spread sheets within their courses and Guo, Wang, and Zhao (2010) discussed six stages of development about the development of rural Chinese teachers' capabilities in using information and communication technology. In these studies, active involvement in authentic design activities and implementation or enactment of technology-enhanced lessons or courses was found to be critical to the development of TPCK (Koehler and Mishra, 2005; Voogt et al., 2013). In planning intervention for the students in this research study TPCK is of central importance for effective teaching with technology. For instance, on reflecting about their experience of bringing successful design experiments to a large-scale urban state-maintained school system, Blumenfeld et al (2000) believed that the effective integration of technology requires teachers to have sufficient computer skills and understanding of how to use computer as a cognitive tool to enhance students' learning and thinking. In a reviewing pedagogy related to the use of information and communication technology (ICT), Webb and Cox (2004) concluded that technology is a catalyst of teaching practice towards a more student-centred, collaborative learning model, given that the teachers have the knowledge of the affordances of ICT in students' learning of particular subject. They also concluded that teachers must have deeper knowledge of technology affordances and pedagogical content knowledge in order to successfully utilise the affordances of technology. However, Hammond and Manfra (2009) believed that pedagogical content knowledge is more important in affecting teachers' instructional decisions during lesson preparation and enactment than the choice of technological tools (Hammond and Manfra, 2009). Learning how to use technology effectively to support student learning was important, in this study, as teachers needed to base their decisions about how, when, and why to use technologies with students not only on their knowledge of the technologies involve but also on their knowledge of their students, their insights about technology's use in the classroom context, and their understanding of how the students' use of the technology would support their curricular goals.

2.2.2 Summary of Teacher Knowledge

The research reviewed show that while much research is still needed to fully support this relationship, as well to test a cross-cultural conceptualization of general pedagogical knowledge, research thus far is beginning to show that teachers' general pedagogical knowledge is relevant to understanding quality teaching as understood by its impact on student learning outcomes in mathematics, which will be discussed in the next section.

2.3 Learning Mathematics

Attention directed to learning theories all have profound implications for the teaching of mathematics to all students, and at all levels.

I have observed over the years that some students find their studies in mathematics to be difficult and unrewarding. There is a tendency for students to opt out of studying mathematics as soon as possible (Brown et al., 2008; Onwumere, 2009). However, mathematics is usually seen to be important and holds a central place in the curricula in the UK and other countries. Mathematical ideas find application in numerous areas of life and in many careers. Thus, negative attitudes among students may have important ramifications for career choices and contributions in wider society. I have already established that students' performance in mathematics is influenced by teaching and methods so this section will look at the development of mathematics competence by critiquing the learning of the subject. The next section reviews theoretical views on learning, the influence of mathematics curriculum on students' learning, cognitive and affective outcomes, student conceptions of learning mathematics and international perspective on mathematical learning.

2.3.1 Theoretical Views of Learning

Learning and knowing are not solely rational or logical activities. Learning and knowledge involve more than social renegotiation and reconstruction of meaning (Bell and Gilbert, 1996; Ford and Forman, 2006; Wood and Reid, 2006). Therefore, the theoretical concerns of learning in this study do not only address cognitive theory but also include social perspectives. Currently, there are several views about learning which influence the learning of mathematics. These views include behaviourism, cognitive theory, constructivism, social learning and situated learning. The discussion that follows situates this research in a body of knowledge, incorporating different views that may be applied or used to inform teaching, curriculum and student learning. This section focuses on the following theoretical views of learning: Social constructivism; Acquisition and Participation Metaphors; and, Sociocultural views of Learning.

Social Constructivism

Social constructivists interpret learning within social and cultural settings from a situated perspective (Smith, 1999). Here the focus is on interpreting learning within language and the social/cultural background and might include the progress of individual learning (Smith, 1999). Smith used a metaphor to differentiate social and individual constructivism. That is, with the social constructivists "individual constructivists cannot see the forest for the trees", while for the individual constructivists "social constructivists cannot see the trees for the forest" (Smith, 1999: p. 413). Thus, according to Smith (1999) both forms lack the ability to see the big pictures of what students learned. Within the mathematics classrooms, at Majac Secondary School, the students in the study were taught mathematics but the teachers were not sure if they (students) were learning and understanding the concepts and therefore the students were identified to undertake interventions.

Confrey and Kazak (2006) critiqued several points of constructivism. For example, some researchers view constructivism as a theory of knowledge and as such, one has to apply its implications for instruction. Confrey and Kazak (2006) argued that teachers lack maturity in applying the tenets of constructivism into instructions.

There are shortages of systematical summaries of constructivist research findings. Social cultural factors are over emphasised among constructivist research (Confrey and Kazak, 2006). While others also raise the concern that not all concepts need to be constructed (Lesh and Doerr, 2003), such as some procedural or imitating work (Lesh and Doerr, 2003). Moreover, there are too many individual concepts in the mathematics curricula, and it is hard for students to construct all of them in classrooms (Confrey and Kazak 2006). In this study it was identified, through semi-structured teacher interviews and student focus groups, that the students did not engaged as active participants in the teaching and learning processes in their classrooms and therefore teachers should have encouraged errors resulting from the student' ideas, instead of minimizing or avoiding them.

Acquisition and Participation Metaphors

The use of metaphors in this study supports the need of especially adopting situated learning theories to fully explain participants/students' learning during the research process, along with the use of other learning theories. Combining metaphors provides a more robust way of explaining learning and or teaching (Sfard, 1998; Richardson, 2003). Sfard (1998) described two methods of learning: acquisition and participation metaphors. As defined, the acquisition metaphor places emphasis on concept development and gaining possession of knowledge. Moderate or radical constructivism, interactionism and sociocultural theories tend to fall in this category (Sfard, 1998). From an analytic perspective, behaviourism and cognitive theories also belong to the category of the acquisition metaphor. Evidence of behaviourism which may be linked to the acquisition metaphor includes 'grasping knowledge' (Peressini et al., 2004; Even and Tirosh, 2008), and passive concept development (Romberg, Carpenter and Fennema 1993; Young-Loveridge, 1995). Evidence supporting these emphases of cognitive theories of grasping knowledge are revealed in the arguments of and von Glasersfeld (2005) and Cobb (2007) who state that knowledge is actively constructed by students. Evidence supporting these emphases on sociocultural theories of grasping knowledge are found in the arguments of Lave and Wenger (1991) and O'Connor (1998) stating that learning occurs not only in individuals but also when interacting within a social context. In this study, during intervention one and two, the students actively engaged in their learning cooperatively with their peers and they developed their own knowledge through learning with and from each other.

The second metaphor, participation can be viewed as "part-whole relation" (Sfard, 1998: p. 6). Learning can be interpreted as a process of participating or taking part in the whole (Sfard, 1998). Hence, one examines the interaction between the part and the whole. The participation metaphor can offer alternative ways to interpret learning and help to avoid labelling people from their achievement, such as in the acquisition metaphor, because people's actions differ each day (Sfard, 1998). For instance, a high achieving student is not necessarily to be labelled as excellent every day; it is dependent each time on how well that student interacts while learning. However, the single use of this framework does not support interpreting learning, because it refuses the objectivity knowledge (Sfard, 1998). For example, Sfard (1998) argued that it cannot explain carrying knowledge in different contexts. Whereas, applying knowledge in new situations is essential in learning or explaining one's competence. Moreover, this participatory framework does not support the weak points in constructivism (including the moderate, radical or social constructivism), which is a lack of understanding of student agreement or consensus with others or the connections of individual concepts with the public ideas, simply because it rejects the objectivity knowledge (Sfard, 1998), such as the social collective form of knowledge which is constructed from students. It is therefore hard to separate these acquisition and participation metaphors, because the actions of acquisition are often combined with the actions of participation (Sfard, 1998). It is also not advisable to only choose one of these conceptual frameworks, since they each serve a different role in learning and a single focus may result in the loss of important meanings (Sfard, 1998). A disadvantage of only valuing the acquisition metaphor occurs when one labels an individual's product as a 'quality mark' based solely on achievement. A participation metaphor does not explain knowledge applied in different contexts (Sfard, 1998). Hence, a focus on just one metaphor is insufficient in explaining learning such as constructivism. The strength lies in combining the advantages of both forms of metaphors (Richardson, 2003).

Sociocultural Views of Learning

The acquisition metaphor was rigorously adopted in educational mathematics research in the last century (Forman, 2014). However, since the late 1980s, there have been new shifts of theoretical frameworks focusing on the social prospects of learning in the mathematics education field (Lerman, 2001). The new growth of theoretical focuses especially, has embraced language and social practices as fundamental and constitutive elements of "consciousness, behaviour and learning" (Lerman, 2001, p.97). Several frameworks have attempted to explain sociocultural views of learning and practice, including ethnographic frameworks (Greeno, 2003), participation metaphor versus acquisition metaphor (Sfard, 1998), discursive psychology (Lerman, 2001), social constructivist perceptions of learning (Smith, 1999; Lesh and Doerr, 2003), communities of practice (Wenger, 1998), situated learning (Lave and Wenger,

1991) and situated cognition (Lave and Wenger, 1991; Graven and Lerman, 2003) and practices (Lave and Wenger, 1991; Boaler, 2003). Some of the above categories are common in many ways and are lacking in clarity, because they are established according to different ideologies which include education (Bell and Cowie, 2000), anthropology, sociology and psychology (Bell and Cowie, 2000; Greeno, 2003; Peressini et al., 2004). However, Lerman (2001: p.97) has integrated some of the above theoretical frameworks, especially those which take account of language and social practices as essential elements of learning, as "social practice theory". This sociocultural theory of learning can be considered in addition to that of cognitive learning theories, because mathematical meaning-generating and learning occurs not only in individual minds but also, it includes participating in socially complex interactions among people and environments (Lave, 1988; Lave and Wenger, 1991; O'Connor, 1998), and culture and history (Wenger, 1998). Vygotsky (1978: p.57) claimed that learning stems from sociocultural interaction asserting:

> 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 the child (intrapsychological). … All the higher functions originate as actual relationships between individuals".

Meaning is generated when participating in sociocultural interaction, then the knowledge and understanding is integrated into personal consciousness. Students' mathematical abilities (for example, including interpretation, explanations, solutions and justifications) should therefore not be seen as being merely individual competence but rather, their abilities should be viewed as simultaneous acts of participating in collective or communal social classroom processes (Simon, 1995; Bowers et al., 1999). According to Lave and Wenger (1991: p.57), learning is never simply a process of transfer or assimilation. Rather, it is complex because "learning, transformation, and change are always implicated in one another". Learning taken in a social context occurs during classroom interactions (Franke et al., 2007), through participation in communities and organisations (Lave and Wenger, 1991) and through social/discourse practices (Wenger, 1998; Boaler and Greeno, 2000). Therefore, learning occurs from multiple dimensions of an individual's integrated activities that include an individual's everyday life experiences (Wenger, 1998), combining both experiences outside and inside of school; collaborative interactions and collective constructive knowledge (Brown et al., 1989, 1996; Mclellan, 1996).

The instructional process in the social learning paradigm is measured by the social interactions (Voigt, 1994) that lead to logical progress (Doise and Mugny, 1984) and the growth of mathematical thinking (Hiebert and Wearne, 1993). Learning is viewed as reproducing and transforming the social structure (Wenger, 1998). Thus, within a culture, people communicate and modify ideas. Social conversation and interaction are significant in developing an individual's belief and learning (Brown et al., 1989, 1996). A social learning theory can inform academic investigations and is also relevant to design activities, organisations and educational policies (Wenger, 1998). Several scholars viewed learning from a participatory metaphor rather than from individualism (Hanks, 1991; Wenger, 1991; Sfard, 1998; Franke et al., 2007). For example, Hanks (1991) viewed learning as "a process that takes place in a participatory framework, not in an individual's mind" (Lave and Wenger, 1991: p. 15), and people engage in sense-making while participating together (Franke et al., 2007). Further, "participation is always based on situated negotiation and renegotiation of meaning in the world. This implies that understanding and experience are in constant interaction-indeed, are mutually constitutive" (Lave and Wenger, 1991: p. 51). However, participation is not easy to be identified, because of the often-unspoken underlying purposes of the teacher, school or society (Franke et al., 2007). Group activities during mathematical instruction provide an opportunity for students to engage in discussions. According to Brown et al (1989,1996: p.39) group activities promote "social interaction and conversation" to occur. Such group activities were evident at the camp intervention when students were asked to work in groups for the mathematics activities and the group work showed that the students improved their critical thinking and problem-solving skills; furthermore, their way of expressing themselves became better. This method helped students learn interactively and efficiently for example, the environmental activities (rock climbing) supported social engagement further.

The role of the environment in learning cannot be ignored as it provides the context for learning. Voigt (1994) refers to Vygotsky's view of the environment and claimed that one's environment and cultural practices seem to influence their learning of mathematics (Voigt, 1994) directly and significantly *and* benefit their development (Kersaint, 2007). Boaler's (2000) study also supports this statement and states that the individual internalizes given mathematical knowledge, which is influenced by cultural practices (Voigt, 1994). Thus, teachers must consider the importance of a learning environment, social practices, and the influence of these social practices on an individual's learning. The aim of a sociocultural approach is consistent with the nature of this sociocultural view of learning to "explicate the relationships between human action, on the one hand, and the cultural, institutional, and historical situations in which this action occurs, on the other" (Wertsch, del Rio and Alvarez, 1995: p. 11).

In order to summarise several of the scholars' theoretical frameworks (for example, Hanks, 1991; O'Connor, 1998; Sfard, 1998; Bowers et al., 1999; Bell and Cowie, 2000; Franke et al., 2007), a sociocultural approach seeks to describe and explain relationships among the processes of learning and meaning generating when participating in activities, environments, sociocultural and historical contexts.

Research about social interaction and mathematics learning has been conducted in different countries. The social interaction patterns in classrooms were found to influence students' knowledge within the cultural context (Wood et al., 2006). Learning occurs during mathematical discussions (Driver et al., 1994; Voigt, 1994; Wood, 1999) as the student negotiates meanings and develops mathematical ideas (Voigt, 1994). From a behaviourist perspective, the teacher might assume that a students' weak performance when learning is due to insufficient opportunities to practice solving problems, whereas a constructivist might refer to the same problem as being due to insufficient opportunities for the student to develop their own understanding. Both views may be accurate and there might be no single explanation to adequately understand students' weak performances when learning (Boaler, 2000). One therefore may use another learning theory to explain more carefully the nature of the problem or rather students' failure in transitioning their knowledge to different situations, for example, a cognitive or situated learning perspective (see discussions in a later section of this study). Moreover, the concepts of social constructivism are different from sociocultural learning perspectives, for example, the theories of Vygotsky (Lerman, 2001). Vygotsky (1978) claimed that learning stems from sociocultural interaction and the generating of meaning is closely associated with culture first, then the new understanding is integrated into an individual level. In contrast, social constructivists emphasize the learning behaviour within the learning processes. They announce that individuals, based on their experiences and previous knowledge, actively construct knowledge (Ernest, 1996) through interacting with people or cultural and social worlds (Hartas, 2010). However, sociocultural perspectives have changed the attention of constructivist research with claims of students' agency, beliefs and abilities in successful learning instead of social cultural issues (Confrey and Kazak, 2006). Therefore, the social-cultural perspective considered the way that different students interacted with their social groups and how these social groups influenced them and how they developed throughout the intervention process, for example, from the start of the study in Year 7 to the end when they were in Year 11the students' social groups affected them differently as they moved between ability groups in mathematics, sometimes term to term or yearly.

2.3.2 Influence of Mathematics Curriculum on Students' Learning

In the UK, mathematics is considered a key subject for many fields. Khan (2012) noted that mathematics is not usually a popular subject and is a subject where students face many problems, with many opting out, after GCSE, as they are allowed. DeCaro (2010) considers that, in the UK, mathematics is poorly taught. However, teachers can only teach what is mandated for them. Very often, teachers are forced to follow the ways prescribed by the NC, the national assessments, GCSE tests, and linked textbooks. Procedures are memorised, practiced and then tested in formal national examinations, credit being given for the correct conduct of procedures leading to correct answers (Alenezi, 2008). A study conducted by Ali and Redi (2012) has shown very clearly that a rigorous curriculum designed by schoolteachers was much more successful than the curriculum designed and by those outside the classroom. Thus, part of the problem in mathematics education may well be in an inappropriate curriculum.

In the UK, the curriculum for secondary teaching (KS3 and 4) is arranged under four broad programmes of study: (1) Number, (2) Measurements and geometry, (3) Algebra (4), and Statistics and Probability. However, if the examinations give the rewards to candidates for the correct conduct of taught procedures, then practicing procedures will become the focus for both teachers and students.

Many studies have considered areas of difficulty in mathematics. For example, Matthews and Pepper (2005) examined that the main reasons for giving up mathematics include lack of satisfaction coupled with boredom along with perceived irrelevance. Nardi and Steward (2003) argue that, at age of 12-15, enjoyment is an important feature for students when seeking understanding. In the current study the focus group students stated that their teachers are not actively engaged with the mathematics they teach and some of the teachers did not display characteristics of care, enthusiasm and engagement. In other words, there was a lack of engagement by all parties.

In a wider sense, research shows consistently that students naturally want to make sense of what they are being taught. This observation stems back to the work of Piaget (Ojose, 2008) and was very evident in a study when she looked at what attracted students into studying physics (Reid and Skryabina, 2002). The principle led to the idea of the applications-led curriculum where the themes being studied were determined by an analysis of the needs of the students in the context of their age, culture and lifestyle (Reid, 2000). Alenezi (2008) considered the place of applications in the teaching and learning of mathematics and noted that this presented very specific difficulties in that working memory could not cope with the mastering of a mathematical procedure, understanding what those procedures meant and seeing how it could be applied. The evidence shows clearly that difficulties in mathematics can largely be explained in terms of the limitations of working memory capacity. In this context, Alenezi (2008) observed that the best way forward is to concentrate on practicing the procedures until these are automated. Automated procedures take up very little working memory space, leaving capacity for the student to consider understanding and applications. However, if the examination procedures reward the correct conduct of procedures and the curriculum is overloaded, there is no time or motive for the hard-pressed teacher to consider either understanding or applications, leaving the student dissatisfied. In considering any mathematical task, the student has to cope with the procedure to be followed and any mathematical representation being used.

With increased achievement requirements from the DfE on students to develop a deep and interconnected understanding of mathematical concepts, more emphasis is being placed not only on the students' capacity to understand the facts in mathematics but also on their capacity to do mathematics (DfE, 2012). There is need for both policy makers and researchers to deepen their knowledge and understanding of the various impacts on student learning when teachers use different curriculum implementation strategies. Student learning outcomes are defined in terms of the knowledge, skills, and abilities that students have attained as a result of their involvement in a particular set of educational experiences. Student learning is influenced by the experiences students go through in the classroom. Therefore, in this study it is not only the materials themselves that impact on learning, but also how the teachers help the students through the teaching interventions to experience the materials. These experiences can be through instructional tasks as well as through teacher-to-student interactions or student-to-student interactions in the classroom.

Murayama et al (2013) states that most students are considering mathematics as difficult. This study examines the difficulties perceived by secondary school students and teachers in learning and teaching mathematics. The study incorporated cognitive and affective reasons that contribute to the difficulty in learning mathematics which will be explored more in the next section.

2.3.3 Cognitive and Affective Outcomes

An extensive body of research (Gottfredson,1997; Kaufman, 2009) has investigated the roles of cognitive factors such as working memory, attention, and processing speed, in mathematics achievement. In contrast, studies (such as, Dowker, 2016; (Carey et al., 2019; Barroso et., 2020) examining the role of affective factors, such as mathematics anxiety, are relatively few, and the mechanisms by which affective and cognitive factors collectively influence different components of mathematical reasoning are poorly understood. In particular, it has been suggested that the impact of affective factors such as mathematics anxiety on early mathematics learning and achievement are also related to numerous cognitive factors such as attention and working memory (Fuchs et al., 2015). However, previous studies

(Zhang et al., 2016; Cui et al., 2017) have predominantly examined the effect of each variable in isolation, and mainly in relation to fluency with numerical operations that place little demand on verbally based mathematics problem solving. Little is known about how these affective and cognitive factors differentially contribute to individual differences in competence in basic non-verbal and verbal mathematics problem solving skills, the latter of which place a greater load on working memory and attention (Bailey et al., 2014). This question has added significance considering the introduction of the NC, which places a greater emphasis on applying mathematical knowledge in real world applications (DfE, 2015). The cognitive and affective demands for these kinds of applications are likely to be different from those invoked in basic numerical fluency and procedural skills.

In the next sub-sections, I will discuss the interrelated roles of affective and cognitive factors on mathematical problem solving with a specific focus on mathematics anxiety and working memory and attention and working memory. I will first review relevant literature and then describe interrelations among these factors and their impacts on student's performance on mathematical achievement.

Mathematics Anxiety

Mathematics anxiety is defined as a negative emotional reaction to situations involving numerical problem solving (Richardson and Suinn, 1972; Ashcraft, 2002). Recent studies using standardised and age-appropriate mathematics achievement measures have shown that mathematics anxiety is negatively correlated with mathematics achievement, even at the earliest stages of mathematics learning (Wu et al., 2012; Ramirez et al.,2013). In this study the students stated, in the focus group interviews, that they have negative views on mathematics teaching and learning and this led to poor performance in them learning mathematics.

Working Memory

As described by Baddeley and Hitch (1974) and Baddeley (1992, 2003), working memory is a cognitive system that facilitates the acquisition of new knowledge and general problem solving by maintaining and storing information from recent past experience. Lower mathematics achievement scores were associated with lower working memory capacity as compared to children with average mathematics achievement (Mabbott and Bisanz, 2008; Friso-Van Den Bos, et al., 2013). With respect to mathematics anxiety and working memory, studies in young adults have shown that mathematics anxiety interferes with the working memory processes that support mathematical computations, thereby resulting in a detriment to performance (Eysenck and Calvo, 1992; Ashcraft and Kirk, 2001). This interaction was clarified in a study by Beilock and Carr (2005) that found a differential impact of pressure on mathematics performance as a function of working memory capacity. The second intervention looked to address issues relating to mathematics anxiety and working memory with the students in order to help them resolve individual concerns.

2.3.4 Student Conceptions of Learning Mathematics

Teachers of mathematics must create opportunities for students to communicate their conceptual understanding of topics. This may involve lesson structures that require a change in pedagogical techniques. Ideas for supporting students in developing conceptual understanding of their mathematics must be provided in resources for teachers. Learning mathematics will be influenced by changes in the teaching of mathematics, as well as by students' attitudes and conceptions of mathematics, and this in turn will affect students’ views about the role of mathematics in their future studies and career. Macbean (2004: p.553) suggested that:

> many factors affect the quality of student learning. The students' conceptions of and approaches to learning, their prior experiences, perceptions, and understanding of their subject and the teaching and learning context can all influence the learning outcomes achieved.

Research into conceptions of mathematics (Reid, et.al., 2003; Petocz, et.al., 2007), utilising phenomenographic analyses (Marton and Booth, 1997), has revealed them to be hierarchical; three levels of conceptions were identified, with the broadest (mathematics is an approach to life and a way of thinking) incorporating an intermediate conception (mathematics is about building and using models, both specific models of aspects of reality and abstract models of logical structures), and this in turn incorporated the narrowest view (mathematics as a toolbox of individual components and procedures, perhaps only numerical calculations). Similarly, Prosser and Trigwell (1999) found that students have a spectrum of conceptions between fragmented and cohesiveness. With a fragmented conception, students were likely to use a surface approach to their study, whilst those with a cohesive conception were more likely to use a deep approach, and this connection has been established in many subject areas, including mathematics.

A mathematics teacher can show and tell about the usefulness of mathematics, while keeping the curriculum focus unchanged on traditional, pure mathematics with few applications. However, instead of a teacher conveying relevance, in many curriculum documents there are recommendations that students should experience the usefulness of mathematics through mathematical modelling activities, in which students themselves use mathematics for solving real-life problems (Stillman et al., 2013; Blum 2015). This aim can be related to a pragmatic perspective on mathematical modelling (Kaiser 2014), which puts utilitarian aims for mathematical modelling activities in classrooms to the fore. This perspective was one of the concerns raised by students in the focus group interviews.

2.3.5 Strategies and Techniques to Support Mathematical Learning

Henson (1988) defined teaching techniques as the teacher's activities in the class to involve students in the subject matter, requiring that students participate in learning activities, share equally with other students and react to the learning experience. The teacher also needs to work with students as a friend, make the learning place more comfortable, organise his/her lesson plans and influence students by using different teaching methods. The teaching goals must be adapted to the needs and interests of students, while teaching strategies should be carefully used to improve learning and make the subject matter useful. According to several studies (Schworm and Renkl, 2006; Ainsworth and Burcham, 2007), these strategies have been found to be significantly related to students' learning achievement.

2.3.6 Teaching Strategies

Dyer and Osborne (1996) stated that students' thinking skills and problem-solving abilities could be developed by teaching activities, especially by the selection of an appropriate teaching approach. Henson (1988) argued that the teacher's paramount purpose is to help students learn and to give real help. He suggested three roles for teachers in planning a unit. The first is to: "identify some of the important ideas or concepts that will be developed in the unit and to explain the importance of this material to the students" (Dyer and Osborne, 1996: p. 17). The second role is to: "give students an opportunity to include areas within the unit that they think should be studied" (Dyer and Osborne, 1996: p. 17). Lastly, teachers need to: "help in selecting activities necessary for developing an understanding of the unit" (Dyer and Osborne, 1996: p. 17). Therefore, researchers (Abraham, 1997; Johnson and Lawson, 1998; Musheno and Lawson, 1999) posit that students achieve best when their learning experiences are constructivist (hands-on/minds-on) in design, for example, active, relevant, applied, and contextual. Learning environments supporting sustained inquiry, for example, a learning cycle approach to instruction, that are rich in concrete experiences show the greatest promise for improving student achievement.

Teaching strategies can be defined as those orientations that the teacher gives to students in order to promote learning; it is about the orientations that the teacher provides to the students with the purpose of developing in them different capacities for the interpretation of the information related to a certain mathematical task. The mathematical task according to (Ding, Jones and Pepin, 2013; Swan, 2013) is considered as that segment of activities addressed in the classroom where students are invited to solve problems, develop mathematical concepts ideas and strategies to perform procedures and thus offer opportunities for learning mathematics. In other words, these tasks contain certain mathematical concepts that are related to the curricular contents because when it comes to developing concepts, there is a strong link with the different topics that the teacher must address; that is, the curricular contents. Anijovich and Mora (2009: p.4) stated that

> It is essential, for the teacher, to pay attention not only to the topics that must be included in the programs and that should be addressed in class, but also, and simultaneously, in the manner in which it can be considered more convenient for those topics to be worked on by the students. The relationship between themes and the way to approach them is so strong that it can be argued that both themes and didactic treatment strategies are inseparable.

Viewed in this way, Anijovich and Mora (2009) recognised that there is a strong relationship between curricular content and teaching strategies. Gonzáles (2009: p.523) stated that, in mathematics, this correspondence is fundamental for student learning, as:

> The way in which it is taught in the classrooms of basic education makes abstract contents prevail, without support in resources that allow building knowledge, going from concrete and semi-concrete representations of mathematical ideas and concepts to synthesis activities that facilitate the abstraction and generalization of the mathematical contents of the level. The way Mathematics is taught is as important as the content.

In this way, teaching strategies can be implemented by the teacher before, during or after addressing specific curricular content. Therefore, teaching strategies can be classified considering the time of use and presentation of the teachers to achieve their objectives within the tasks. Indeed, the authors Díaz and Hernández (2010) classify the teaching strategies according to the time of use and their respective presentation, thus generating three categories called: pre-instructional, co-instructional and post instructional. Therefore, ccognitive strategies, such as, repetition, organizing new language, summarizing meaning, guessing meaning from context, using imagery for memorisation are learning strategies students use in order to learn more successfully. Cognitive strategy instruction develops the thinking skills that will make students strategic, flexible learners and teachers are encouraged to use these strategies, such as attention, rehearsal in working memory, retrieval from long-term memory, and metacognitive monitoring.

By expanding the teaching strategies used by teachers, the literature intends to propose strategies that help to restructure students' prior conceptions of mathematical knowledge (Ruppenthal and Chitolina, 2015). It is interesting to be able to show the teacher that there are teaching strategies that can be implemented within their pedagogical practice. For example, there are teachers who use teaching strategies where the construction of the different concepts addressed in the tasks is not their focus, which limits the student to explore the different concepts submerged in the proposed tasks.

In the next section, the research focuses on factors contributing to effective mathematics teaching and learning in secondary schools (Years 7–11) as mathematics has always been a difficult subject for most students in secondary schools (Hamid et al., 2013; Ahmad and Shahrill, 2014; Mahadi and Shahrill, 2014). Research has demonstrated that each of the following was important for understanding teacher effectiveness, especially for the teaching of mathematics:

a) Classroom teaching-how the teaching is organised and applied by the teacher (Fennema and Franke, 1992; Ball, Lubienski and Mewborn, 2001), and;

b) Teacher beliefs-those about teaching and mathematics appear to be important in shaping practices (Askew et al., 2000), but teaching practice is not always consistent with beliefs (Thompson, 1992; Raymond, 1997).

2.3.7 Classroom Teaching

Thorndike (1922) defined teaching as the methods used to help students achieve the learning goals valued by society. Gage (1978: p.14) defined teaching as "any activity on the part of one person intended to facilitate learning by another". Although these definitions contain much of what modern classrooms exhibit, they are incomplete because they seem to treat teaching as a one-way relationship: teachers acting on students. Teaching is influenced by students and has a multi-directional quality. Cohen, Raudenbush and Ball (2003: p.122) captured this quality by saying that "instruction consists of interactions among teachers and students around content". Instruction can occur in a wide range of institutional settings and configurations, but for my purpose the school classroom is my point of focus.

Classroom teaching is accepted as a central component for understanding the dynamic processes and the organisation of students' mathematical thinking and learning (Rogoff and Chavajay, 1995; Cai, 2004). Due to classroom teaching playing such a central role in students' learning, researchers have long tried to characterise the nature of the classroom teaching that maximises students' learning opportunities (Good and Brophy, 1994). Seah (2007) stated that effective teaching is undoubtedly the most important objective in school mathematics education. Larson (2002) recognised that some mathematics teachers are more effective than others. Even though effective teachers of mathematics may tend towards student-discovery or teacher-directed pedagogical teaching, they share certain common traits in how they deliver mathematics teaching.

Although there is no universal agreement as to what effective mathematics teaching should look like, no one questions the idea that the teaching practices of teachers are influenced by both their cultural beliefs and conceptions of effective teaching (Buehl and Beck, 2015). In fact, teachers do draw upon their cultural beliefs as a normative framework of values and goals to guide their teaching (Bruner, 1996). A teacher's manner of presenting mathematics is an indication of what he/she believes to be most essential, thereby influencing the way in which students understand and learn mathematics (Cooney, Shealy and Arvold, 1998; Cai, 2004). Although there is a vast range of literature (Johnson et al., 2014; Bainbridge, 2010; Martin, 2010, Pan, Zang and Wu, 2010) about the effects of teaching practices on student motivation to learn, few studies have specifically examined teachers' beliefs about how to motivate students to engage in mathematics learning and activities.

2.3.8 International Perspective on Mathematical Learning

International performance indicator studies (such as PISA, Trends in International Mathematics and Science Study (TIMSS)) focused researchers' interests on variables affecting mathematics performance from both psychological and socio-cultural perspectives (Mullis, Martin and Foy, 2008; OECD, 2010). A recurrent theme in cross-cultural studies is that English students' performance in the mathematics domain has remained stable since 2006 (Geary and Salthouse, 1996;

Imbo and LeFevre, 2009). Although England's average mathematics score has remained stable since 2006 (OECD, 2015), there are 18 countries where the mean score is at least a third of a year of schooling ahead of England, and 36 countries where the mean mathematics score is at least a third of a year of schooling below. Although mathematics education is considered to be important in English education, considering the high emphasis on mathematics summative assessments at GCSE, limited empirical studies are available that explore the variables affecting learning performance from a variety of perspectives. This lack of in-depth research might be due to barriers, limited resources and the limited power of local educational authorities (Li, 2006).

Therefore, these steps were taken to provide a thorough analysis of the literature on mathematical learning. To develop an overview of studies about mathematics teaching and learning, the approach:

- analysed several established theoretical models and linked them to mathematics learning;
- centred on models that studied mathematics learning and looked for influencing processes and variables (Brownell, 1928; Geary and Hoard, 2005); and,
- introduced the cultural context of the English education system.

2.3.9 Summary of Mathematics Learning

Understanding how humans learn has developed dramatically over the past century. Numerous domain-specific learning theories have each contributed to our understanding of how learning occurs. Each theory tends to describe its learning mechanism in isolation from other learning mechanisms, which allows for targeted study design. This approach, however, can limit our understanding of the bigger picture. No single mechanism or set of processes can explain human learning in its entirety. In the next section I will explore the use of mathematics interventions in secondary schools due to its new double weighting as an indicator of progress (Cassidy, 2014).

2.4 Mathematics Interventions

The purpose of intervention is to support students who are 'at risk' of mathematics difficulties, either due to their underachievement in mathematics which acts as a precursor for later mathematics difficulties (NCTM, 2011; Toll and Van Luit, 2012). It is understood by schools that they should provide interventions to students as soon as they demonstrate the need. Cassidy (2014) suggested that offering interventions distracts from high quality teaching, but other researchers highlight the necessity of their use for supporting students who are not able to access the curriculum in a standard classroom with as many as 20% of students requiring additional support for specific reasons. Common barriers to progress include specific learning needs, low attendance, anxiety, misconceptions, and poor behaviour (McCormack, 2013). The purpose of intervention, therefore, is to systematically provide every student with the additional time and support necessary for success (Buffman et al., 2010). Teachers use interventions to improve mathematics skills and achievement, and early intervention is important in order to improve the potential of young students for academic success (Fox, Levitt and Nelson, 2010). At the time of writing, schools continue to struggle with the best methods and strategies to implement effective mathematics programs while working towards closing achievement gaps. Many intervention programs have been designed and developed in the UK, for example, ‘The efficacy of interventions on pupil attainment in GCSE mathematics’, (Leech, 2019).

There are many different research-informed interventions strategies in mathematics, and it is available to schools that not only offers the prospect of raising levels of student progress and achievement. It is important to recognise that there is a substantial evidence base available to schools that can be used to evaluate the effectiveness of many of the interventions they may use currently or that are under consideration. Therefore, it remains a matter of profound concern that, despite the relative accessibility of this evidence, teachers and school leaders continue to have interventions imposed on them that are not only of limited demonstrable benefit to students.

OFSTED, (2009) explains there is no single intervention strategy that will solve the issue of low performing mathematics achievement. Rather, success comes from ongoing, continued intervention programs that are targeted to students’ needs, assess students regularly, monitor student progress, are well-managed by administrative staff, and are implemented by highly trained and knowledgeable staff (OFSTED, 2009). Literature reveals that there is no single most effective solution for mathematics interventions, Dowker (2009) and Ofsted (2009). What has been established as the best support for the students, in the current study, is the professional discretion of their teachers (NCTM, 2011). In the next section I will discuss barriers to the teaching-learning of mathematics in secondary schools and how they impacted on the teaching-learning outcomes.

2.4.1 Barriers That Exist in Implementing Intervention Strategies

There are a variety of barriers that exist when implementing intervention strategies in mathematics, but intervention strategies are more likely to succeed when there is a shared commitment to the success of the intervention program (NCTM, 2011). The main implementation barriers are time, resources, staff knowledge/training, issues with communication, low expectations, and inaccurate metrics to measure improvements (NCTM, 2011). Table 2.3 details the intervention strategies with explanations of barriers to interventions and recommendations for dealing with the barriers.

Table 2. 3 Barriers to Intervention and Evidence-based Recommendations

Intervention	Barriers to Intervention	Recommendations
1. Universal screening	School boards and schools may find it difficult to allocate time for universal screening (Gersten et al., 2009). Some people might question why we are testing students who are doing fine (Gersten et al., 2009).	Screening all students to ensure students are on the right track, and students who are at-risk are not being missed (Gersten et al., 2009).
2. Ongoing monitoring of at-risk students	Assessment data may be collected too late (such as the end of the year).	Students at-risk should be assessed early and continuously. (Gersten at al., 2009)
3. Maintain high expectations	Sometimes teachers teaching at-risk or 'low ability groups' have low expectations for students and do not truly believe the students can learn the content (Sullivan, 2011).	Teachers must set high goals for all students and challenge students (Sullivan and Gunningham, 2011).
4. All grade levels should include 10 minutes of arithmetic practice per class	Students might find practicing arithmetic every class boring (Gersten et al., 2009). Curricular materials may not include sufficient activities (Gersten et al., 2008).	Try to make arithmetic practice fun, using games, flashcards, or apps (Gersten et al., 2008).
5.Teach mathematics in a multidisciplinary and interdisciplinary manner	Some teachers may not have the knowledge to teach mathematics in a multidisciplinary and interdisciplinary manner (European Commission, 2013).	Government curricular materials should include activities that utilize a multidisciplinary and interdisciplinary manner (European Commission, 2013).
6. Use monitored high-quality small group instruction when necessary	Students are taught materials they already know; year-long, small groups outside of the classroom may be ineffective (Sullivan, 2011).	There should be a clear intention that small-group tutoring is not permanent, and an exit strategy exists (Sullivan 2011)
7. Culturally sensitive curriculum and teaching	Curricular materials may not include activities that teach math in a culturally sensitive manner	Districts and schools should provide materials that teach mathematics in a culturally sensitive manner
8. Ensure teacher knowledge of mathematics and intervention strategies	Some teachers may not be familiar with mathematics content knowledge or intervention strategies (Gersten et al., 2009).	Schools should provide ongoing and high-quality professional development on mathematics content and teaching pedagogy (Gersten et al., 2009).

Table 2.3 presents barriers and recommendations which can be implemented within this study to support the students to start the process of overcoming affective barriers to mathematical learning. All these intervention strategies are multi-tiered approaches to identify and address learning needs of students. The strategies that teachers use can help to provide structure and clear expectations of behaviour for students as well as clear protocols for staff to use when working with students. Therefore, these interventions provided a useful reference point for preparations of materials and resources for the intervention in this study. In the next section I will discuss why we need mathematics interventions in secondary schools.

2.4.2 The Need for Interventions

Frost and Durrant (2003: p.12) poem, '*Revelation*', speaks of the tendency of humans to hide their true identity from others while at the same time hoping that someone will find them out.

> We make ourselves a place apart, behind light words that tease and flout, but oh, the agitated heart till someone finds us really out. Tis pity if the case requires (or so we say) that in the end we speak the literal to inspire the understanding of a friend. But so, with all, from babes that play at hide-and-seek to God afar, so all who hide too well away must speak and tell us where they are.

In a poem that is most likely talking about faith and love, from a teacher's standpoint it may have a deeper meaning. In 1996, Michael Polanyi put forward the concept of 'tacit knowledge' in a philosophy, entitled 'Personal Knowledge', he divided knowledge into two categories: explicit knowledge and tacit knowledge. Explicit knowledge is a kind of knowledge that can be expressed by written text, charts and mathematical formula; tacit knowledge is hidden in the hands and minds of knowledge main bodies, reflected in abilities, knacks, skills, insight, experience, mental models, and understanding of group members, which are difficult to express accurately with characters and languages, most of them are hard to be encoded or even cannot be encoded (Szulanski, 1996). Tacit knowledge or implicit knowledge; as opposed to formal, codified or explicit knowledge; is knowledge that is difficult to express or extract, and thus more difficult to transfer to others by means of writing it down or verbalising it. Tacit knowledge can include personal wisdom, experience, insight, and intuition. This kind of knowledge existed in the individual knowledge structure with a large number, which is even more than that people can express in words. Thus, we should gain more tacit knowledge by learning, and share it by spreading and exchanging, playing its proper value in order to promote the healthy development of human knowledge.

In face of the changes in the conception of the epistemology of mathematical learning, many scholars (Schoenfeld 1992, Romberg 1992, Winbourne and Watson 1998) have been putting emphasis on the importance of creating learning environments where teachers and students would be involved in actual mathematical experience. On account of that, Ernest's (1998) model re-signifies mathematical learning when it characterises it as being mainly tacit. In other words, such an approach tells us that a great deal of mathematical knowledge cannot be either taught or learned by means of explicit transmission. We should transform tacit knowledge reasonably according to its specialty and make it easier to be understood. Tacit knowledge will become a new power of creating knowledge by spreading and applying widely in this way. Thus, if only students could tell us where they are. "In the absence of such a revelation, the teacher has to practice the assessor's art: find out what the students know and can do- and lead each to the next upward step" (Shuman and Scherer, 2014: p.7). In this sense, individualised, component-based approaches to mathematics intervention have been found to be highly effective. As no student is the same, implementing an intervention programme for mathematics can be very challenging as each student has their own unique difficulties. Ofsted (2010) report states that there was not a single universally effective intervention programme; but success was determined by how well students were targeted, assessed, and monitored as well as how the overall programme was managed. Therefore, tacit 'know how' as well as propositional knowledge as part of mathematical knowledge is that it takes human understanding, activity and experience to make or justify mathematics. The students carried out symbolic procedures or conceptual operations. For example, to know the algebraic manipulations or to carry out the operations involved in foreign exchange with money. Thus, what an individual knows in mathematics, in addition to publicly stateable propositional knowledge, includes mathematical 'know how'. The next section discusses examples of mathematics interventions across different countries because understanding effective practices from the global mathematics community is a valuable step for any researching professional.

2.4.3 Mathematics Interventions in Other Countries

Different countries have different intervention policies. For example, in many parts of Europe (Estonia, Ireland, Spain, Poland, Norway), central authorities decide on intervention policy. In Scotland and Denmark, more general recommendations are provided, while in Czech Republic, Latvia, Hungary, Sweden, and Iceland no central recommendations are given, and each school must decide what is best for them (European Commission, 2013). The most typical supports provided to low achievers include individualised teaching, teaching assistants, peer-tutoring, collaboration, and adaptation of curriculum (European Commission, 2013). Table 2.4 outlines a variety of examples of interventions from other countries.

Table 2. 4 Examples of Interventions from Different Countries

Intervention Strategy	Examples of Interventions from Other Countries
1. Universal screening	In Norway, the use of diagnostic tests, national tests, and early interventions are used as screening for all students (European Commission, 2013).
2. Ongoing monitoring of at-risk students	In Poland, the Ministry of National Education created a program that monitors at-risk and high-risk students through early diagnosis of difficulties (European Commission, 2013).
3. Maintain high expectations	In Sweden, the National Agency for Education points out that teacher expectation is an important factor in student motivation to learn mathematics (European Commission, 2013).
4.All grade levels should include 10 minutes of arithmetic practice per class	In the United States, there are a variety of numeracy intervention programs targeting arithmetic, including: Fraction Face-Off!, I CAN learn pre-algebra and algebra, and Do the Math (Hanover Research, 2014).
5.Teach mathematics in a multidisciplinary and interdisciplinary manner	In Estonia, Greece, France, Italy, Portugal, and the United Kingdom, mathematics curriculum focuses on cross-curricular teaching (European Commission, 2013).
6. Use monitored high-quality small group instruction when necessary	In France, the Ministry of Education allocates 2 hours per week for small group or one-to-one teaching (European Commission, 2013). In Spain, Ireland and Slovenia, small group tutoring is provided for up to two hours after the normal school day. In Spain, small group instruction is provided by university students or teachers (European Commission, 2013). In Australia, the intervention Extending Mathematical Understanding (EMU) is a short program that includes tutoring for 6-7-year-olds on number learning (Sullivan, 2011).
7.Culturally sensitive curriculum and teaching	Australia's Council for Educational Research recommends using culturally sensitive curriculum and teaching to improve Indigenous mathematics achievement. For example, in Australia The Garma Mathematics Curriculum (2007) incorporates Indigenous ways of knowing in the mathematics curriculum (Sullivan, 2011).

8.Ensure teacher knowledge of mathematics and intervention strategies	In Belgium (French Community), Estonia, Lithuania and Liechtenstein, student mathematics assessment data are used to inform teachers' professional development learning mathematics content and intervention strategies (European Commission, 2013). In Denmark, teachers reported they found mathematical communication, problem-solving, and understanding the role of mathematics challenging and this information is used to create teacher training (European Commission, 2013). In Finland, the Ministry of Education maintains a website for teachers with information on the most common student learning problems in mathematics, computer instruction learning modules, and diagnostic tests. Teacher professional development is also free of charge (European Commission, 2013).

Table 2.4 looked at intervention research that sought evidence about what kinds of interventions will contribute to desirable student outcomes, (Doig, McCrae, and Rowe, 2003; Ingvarson, et al., 2004; National Mathematics Advisory Panel, 2008). Hiebert and Grouws, (2007). In their synthesis of international research, researchers argued for a more detailed, richer, and coherent knowledge base to inform policy and practice as mathematics is widely understood, it plays a key role in shaping how individuals deal with the various spheres of private, social, and civil life. Yet today, as in the past, many students struggle with mathematics and become disaffected as they continually confront obstacles to engagement. In order to break this pattern, it is imperative that teachers understand what effective mathematics interventions look like. In the next section I will discuss characteristics that supports successful interventions.

2.4.4 Characteristics of Successful Mathematical Interventions

Mathematical interventions have proven effective at improving mathematically able students, and many of these interventions focused on students' procedural fluency (DfE, 2012; Karagiannakis, Baccaglini-Frank and Papadatos, 2016). Intervention should be consistent throughout secondary education and not concentrated in the final year when it is often too late (Ofsted, 2009, Welsh Government, 2012). Many schools are now trapped in a cycle of focusing all support on students closest to their final examinations so there is little resource to spare for other year groups. By leaving intervention until the last minute, schools are developing 'home-grown' underachievement (Ofsted, 2009). Looking at Years Seven to Eleven as a whole ecosystem for support would seem to be a more efficient use of a school's resources. The next section discusses Response to Intervention (RtI) as a process for raising mathematics attainment.

Response to Intervention (RtI)

While not intentionally designed as such, the interventions in this study have evolved to mirror the conclusions of research conducted by Lembke, Hampton, and Beyers (2012) whose study identified the critical elements of Response to Intervention (RtI) in mathematics. In their study, Lembke et al (2012) described the three tiers of mathematics instruction as a multi-step approach to providing services and interventions to students who struggle with learning at increasing levels of intensity. RtI is a process that allows teachers to determine the necessary supports or interventions (Brown-Chidsey and Steege, 2010). These supports and interventions must be used to supplement the core curriculum, not replace it (Fuchs, 2008). RtI should be part of the bigger picture of allowing all students the same educational access and opportunities (Brown-Chidsey and Steege, 2010). According to Fuchs and Fuchs (2001), all students will have access and opportunity to a rigorous and challenging curriculum; however, with RtI, interventions are implemented to meet the needs of all students. According to Danielson (2009), a key component to the success of any intervention is matching the student with the appropriate supports which seems to agree with Duffy and Scala (2012: p.18) who stated:

> Response to intervention is a framework used to ensure that students receive the supports they require for success, and, when implemented throughout an educational system, it also can inform the kinds of supports that might benefit adults in the system.

When the Rtl process is implemented successfully, there are many advantages: (a) assessment data reflects student performance over time rather than a snapshot; (b) early intervention leads to fewer special education referrals; (c) student performance data guides instructional decisions and (d) immediate intervention (Wiley et. al., 2008). It is then expected that the design for the delivery of instruction and assessment is based on progress monitoring data with an overall goal of improving student achievement ((Halverson et al., 2007; Mandinach and Jackson, 2012). According to Brown-Chidsey, and Steege (2010: p.2), “there is no one right way to set up RtI practices. Every school needs to plan, set up, and evaluate its own RtI plan”.

Since the process of RtI is grounded on supports for students based on individual needs, the mathematics teachers at Majac Secondary School met and discussed in a departmental meeting which student needed intervention and how the intervention would be made available to them. Furthermore, the RtI process included the recommendations of tiered interventions to address skill deficiencies that may prevent students from achieving the core content.

According to the National Center on Response to Intervention, (2010), the three tiers are described as: (1) Tier I is high quality core instruction where all students receive research-based instruction that meets the needs of approximately 80% of the students; (2) Tier II is evidence-based interventions that are used in addition to the core, is mostly teacher led small groups and utilises ongoing progress monitoring for approximately 15% of the students; and, (3) Tier III is individual interventions with one-on-one instruction for students who showed minimal response to the primary interventions. Tier III includes increased time and increased feedback and is designed for approximately 5% of the students.

Lembke et al (2012: p.267) described students appropriate for tiered interventions as "students who fall below benchmark scores on universal screening" but who are typically not earning "the lowest scores". Within these tiered interventions, students receive teaching that is "explicit, systematic, and supplemental to the core curriculum" with opportunities for students to communicate about their learning and with frequent feedback from the teacher (Lembke et al., 2012: p. 267). Furthermore, these interventions are described as essential for students who also fall significantly below grade level performance. Lembke et al's (2012) describes many of the students in the study who have struggled to be successful in their regular mathematics classes and they just needed tiered interventions, such as small group and peer-assisted structures, to support their learning.

When considering the two stages of the interventions in the study, after school small group and the mathematics camp, both focused on learning time, building relationships, using varied instructional strategies, cooperative learning, basing instruction on student need and active engagement. The last three seem to be what differentiate this study's research interventions from other mathematics interventions. Most interventions include extending time, focusing instruction and using a variety of instructional strategies. To replicate these principles alone would not have resulted in the improvement seen with the student participants in this study. The uniqueness and effectiveness of this intervention is due to the response to immediate student need, the development of positive student-student and student-teacher relationships.

This type of instruction requires a paradigm shift for many teachers because it is about knowledge (Ravitz, 2000). Past practices, at Majac Secondary School, have consisted of teaching all students the same content, with the same delivery and evaluation procedures. For the 21st century, learning must move towards creating critical thinkers, who are highly engaged and responsible for their own learning, which must be based on their current knowledge base. This type of learning requires data support systems to identify such a knowledge base and to monitor subsequent progress (Duffy and Cunningham, 1996). According to field studies performed by Hughes and Dexter (2012) on RtI they stated that it appears that more studies that include a focus on secondary school levels are needed to establish the breadth of impact for RtI programs. In this study, the RtI was delivered to ten Year 11 students who were at the risk of not achieving their target grades in all ability sets in mathematics, at Majac Secondary School. RtI was delivered in an after-school session and at a mathematics camp in preparation for the student participants final GCSE mathematics exams. The development of the interventions, training and materials was led by Ms Hanekom and me.

A limitation of RtI research has been noted by others in the field such as, Division for Learning Disabilities (2007), Fuchs and Deshler (2007), and National Joint Committee on Learning Disabilities (2005). However, in the current study I have used students from a comprehensive school and who were underperforming in regard to their targets grades set by the school's data system based on previous attainment at KS2 and KS3. The area to focus on would then be the purpose and design of the model using RtI components. However, according to Buffum, Matto and Weber (2010), RtI should not be a process developed to simply raise student test scores, but rather a process used to help students realise their hopes and dreams and prevent any discouragement due to the belief that it cannot be achieved. Once teachers understand the urgency of their work and embrace it based on a fundamental purpose, then it seems improbable that any student could fail (Buffum, Matto and Weber, 2010). Truly individualised instruction is created when time is the variable and learning is the constant, not vice versa. Omitting time as a constant, allowing variation based on student need, is a core essential to any intervention intended to promote student learning. The formula for learning looks like this: Targeted Instruction + Time = Learning (Buffum et al., 2010). The success of this learning formula includes the relationship between the teacher and student. Thus, Ms Hanekom volunteered to be part of the action research cycle of interventions to support the students in her classes and also, to advance her skills and abilities through engagement and participation.

2.4.5 Summary of Mathematics Interventions

It is a challenge to conduct research on mathematical intervention because there is not one standard way to implement an intervention model (Van Der Heyden et. al., 2007). Therefore, it is difficult to conduct wide scale research on mathematical intervention because it varies from school to school. However, there has been research conducted on the type of assessments used, progress monitoring, and effective instruction both in general education settings and intervention classes. Harlacher, Walker, and Sanford (2010) conducted a literature review to find instructional practices that improve academic performance. They discovered that fidelity of curriculum, the curriculum itself, and behaviour management were key areas for success within the tiers. Furthermore, Coleman, Buysse, and Neitzel (2006) conducted a research synthesis of 14 empirical articles on RtI. They concluded that RtI is a viable alternative to the Intelligence Quotient (IQ)-discrepancy model in identifying academically at-risk students. However, when analysing the studies, they determined that the definition of RtI varies in how it is implemented and evaluated. Most models have similar components, but there is no consensus on "specific assessment or data monitoring procedures, the nature and focus of specialised intervention strategies, who delivered the interventions, the duration and intensity of the interventions, and benchmarks used for determining when a new phase should be initiated for individual children" (Coleman et al., 2006: p. 27). Coleman, et al (2006) also found many of the studies they analysed only focused on a specific intervention or interventions and did not look at any RtI models comprehensively, including assessment and interventions. Furthermore, Coleman et al (2006) found students identified as learning disabled decreased if they received interventions beginning in kindergarten and that many of the interventions in the studies, they examined addressed literacy or phonological awareness. Some gaps in their examinations of RtI studies included mathematics, social development, and behaviour interventions. Overall, Coleman et al (2006) concluded that RtI is beneficial in that it uses research-based instruction, all students benefit from it, it reaches students at an early age, and it monitors progress or lack of progress through assessment. Research for RtI is ongoing, but there is extensive research on individual parts (Burns, 2010). For example, research has been conducted on the RtI components of scientifically based instruction, valid and reliable measures used to monitor student progress, and evidence-based, intensive interventions (Hughes and Dexter, 2011). There are still gaps in research in finding and implementing appropriate RtI models for secondary schools (Burns, 2010). Hughes and Dexter (2011) state that although research has focused on the individual parts of the RtI model, there still needs to be research conducted on the RtI model as a whole. Therefore, this study is focusing on a method design which I used to support the students in study.

For some time, the mathematics education community has sought to involve students more actively in classroom mathematical discussions but realising this goal has been problematic. This study will next discuss socio-mathematical norms which emerged and were important concepts to this study.

2.5. Socio-mathematical Norms

The construct of socio-mathematical norm was first promulgated by Cobb and Yackel (1996) and resulted from a consideration of the relationship between social norms and mathematical argumentation. Cobb and Yackel (1996: p.461) define socio-mathematical norms as "normative aspects of mathematics discussions specific to students' mathematical activity", indicating that socio-mathematical norms are a special subset of social norms that apply uniquely to mathematics. Yet this definition seems somewhat vague and unsatisfying. ‘Students explain their thinking when providing an answer’ would be a social norm according to this definition, since there is nothing in it specific to mathematics. But what about ‘students explain their mathematical thinking when providing an answer’? This is essentially the same social norm as before except that it has now been limited to a mathematics context. Would it now be a socio-mathematical norm? Is it now “specific to students’ mathematical activity?” (Cobb and Yackel, 1996: p. 461).

In an attempt to further clarify Cobb and Yackel’s (1996) definition, I propose the following definition: socio-mathematical norms are a subset of social norms that necessarily require specific mathematical content knowledge in order to be understood. For example, ‘students should explain their mathematical reasoning’ would be a social norm. It details how students should interact with others and talk about mathematics. However, students do not necessarily require any specific mathematical content knowledge to understand what it means to explain their reasoning. However, a more specific expectation of what constitutes an acceptable explanation, such as ‘explaining your reasoning means appealing to a mathematical basis of previously established facts, theorems, and relationships’ necessarily requires certain mathematical content knowledge.

To understand this socio-mathematical norm, students must understand what a mathematical basis is and how to appeal to it. Thus, the statement ‘students should explain their reasoning by appealing to a mathematical basis consisting of established facts, theorems, and relationships’ is a socio-mathematical norm. To further illuminate the difference between social and socio-mathematical norms, I now provide several more examples. ‘Students should find multiple different solutions’ would be a social norm because no specific mathematical content knowledge is required to understand what this norm requires. A more detailed expectation of what constitutes a different solution might transform this social norm into a socio-mathematical norm. The statement *students should find multiple different solutions by decomposing and recomposing the numbers differently* would be a socio-mathematical norm. To understand what this norm requires, students must understand what it means to decompose and recompose numbers. The statement *mistakes should be used to explore reasoning* is a social norm. However, a clarification of what kind of reasoning should be explored, such as proportional reasoning, would make this a socio-mathematical norm as students must understand what proportional reasoning is in order to understand what the norm requires. Thus, *mistakes should be used to explore proportional reasoning* would be a socio-mathematical norm.

These examples illustrate a key relationship between social and socio-mathematical norms. Socio-mathematical norms are the more specific of the two and usually consist of a social norm with an additional clarification that invokes mathematical content knowledge. In the examples given above, the socio-mathematical norms clarified more specifically what explaining reasoning means, what a different solution entails, and what exploring incorrect reasoning looks like. In each of these cases, different pieces of mathematical content (basis, decomposing/recomposing, proportional reasoning) were invoked as the criteria by which to make this clarification. These examples then illustrate how socio-mathematical norms complement and clarify social norms. While I believe that my definition helps to clarify Cobb Yackel’s (1996) distinction between social and socio-mathematical norms, there is still a certain amount of unavoidable ambiguity between the two.

Consider the following statements: a) students should show their work, b) showing work means creating a visual representation. c) showing work means creating a visual representation that illustrates the mathematical generality of the claim. By my definition, (a) would clearly be a social norm, but what about (b)? It would appear to be a social norm as well, since no specific content knowledge is required to understand what a visual representation is. But what if this visual representation is specified to be a graph on the coordinate plane? Then specific content knowledge would be required and hence it would become a socio-mathematical norm. Now consider (c). understanding mathematical generality, such as the domain over which a claim applies, is a key (and often difficult) concept in mathematics. Hence, (c) would be a socio-mathematical norm. But what if the word mathematical was removed from (c)? Generalising is not an activity specific to mathematics. We make generalisations about people, activities, and other things in everyday life. Therefore, it seems that (c) would not be a socio-mathematical norm if the word mathematical were removed.

A similar issue arises with the statements below. d) students should explain their thinking, e) explaining thinking means providing computations, f) explaining thinking means providing computations within the context of the original problem. The first statement is a social norm, but the remaining two are more difficult to determine. Do students need specific mathematical content knowledge to understand (e)? They certainly must understand what computations are. Although this is an extremely basic piece of content knowledge, it is nonetheless mathematical content knowledge, so I would consider (e) to be a socio-mathematical norm. However, others might consider the concept of computation to be so basic that they might classify (e) as a social norm. Statement (f) is similar to (e) but it includes the ability to contextualise one's computations. Is this ability to contextualise computations part of mathematical content knowledge? I would argue yes for the same reason given for (e). These examples all serve to illustrate that the boundary between social and socio-mathematical norm can be very thin and even debatable at times.

A minor clarification or specification can often be the difference between the two. In other cases, it is questionable whether a certain skill or piece of knowledge, such as understanding generality, computations, and contextualisation, is specific to mathematics or not. In categorising norms, I will attempt to clarify if I think a particular categorisation is debatable and why so that the reader may make an informed decision. Research suggests that socio-mathematical norms may determine whether social norms actually lead to mathematically discussions. In the classroom that McClain and Cobb (2001: p.247) observed the teacher repeatedly asked for different solution strategies, but students would often contribute repetitive ideas, resulting in discussions "that did not contribute to the mathematical agenda". The teacher stressed that she wanted different solutions but failed to clarify her criteria for what different entailed. This teacher had established a clear social norm but had failed to clarify a corresponding socio-mathematical norm, limiting the effectiveness of the social norm. Eventually, the teacher explicitly clarified what constituted a different solution. This led to the classroom discussions becoming more productive as students now had mathematical criteria to appeal to as an authority in justifying whether or not their solutions were different from others. Kazemi and Stipek (2001) investigated four elementary classrooms (in the US) that all demonstrated productive social norms and found that differing socio-mathematical norms explained whether a classroom had a high or low emphasis on conceptual thinking. In this study I define productive socio-mathematical norms as socio-mathematical norms that seem to be correlated with productive mathematical discussions. Known productive socio-mathematical norms include the expectations that students explain the rationale for their computations rather than just summarising the computations themselves (Clement, 1997), compare their solution strategy to others' using explicitly defined criteria (McClain and Cobb, 2001), use mistakes to explore mathematical thinking and contradictions (Kazemi and Stipek, 2001), and come to a group consensus through mathematical argumentation during collaboration (Kazemi and Stipek, 2001). All these known socio-mathematical norms, listed above, will be explored through the interventions in this study.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

McNiff and Whitehead (2009: p.53) suggest that action research operates around three key tenets, "the story of the action", the story of the research and the "significance" this has to knowledge. This methodology chapter represents the story of the research-and provides a rationale for the epistemological stance, research design and methods adopted in this study. Ethical issues and research limitations will also be documented. Qualitative data sources included semi-structured interviews with teachers, focus groups with students and lesson observations with students and teachers.

3.1 Epistemological Approaches to Research

Ontological and epistemological positions impact on the way research is conducted and there are many different positions taken by proponents of various philosophical traditions. As a researcher, it is important to understand the different ontological, epistemological and methodological stances so that the most suitable methods for answering specific research questions can be identified (Connolly, 2011).

The challenge I faced as a researching professional was to decide on the best data collection tools or procedures to extract the relevant information from data and use it in a meaningful way. This section critiques relevant paradigms of research and how knowledge is understood and explored within.

3.2. Research Paradigm

The word paradigm was first used by Thomas Kuhn (1962) to represent a philosophical way of thinking (Kivunja and Kuyini, 2017). A paradigm can be understood as a set of beliefs that represents a worldview (Mackenzie and Knipe, 2006). It constitutes the abstract beliefs and principles that shape how I see the world, and how I interpret and act within that world. When I say that it defines my worldview, I mean that a paradigm constitutes the abstract beliefs and principles that shape how I see the world, and how I interpret and act within that world. It is the lens through which I look at the world. It is the conceptual lens through which I examine the methodological aspects of this study's research project to determine the research methods that will be used and how the data will be analysed. Guba and Lincoln (1994) who are leaders in the field define a paradigm as a basic set of beliefs or worldview that guides research action or an investigation. Similarly, qualitative researchers, Denzin and Lincoln (2000), define paradigms as human constructions, which deal with first principles or ultimates indicating where the researcher is coming from so as to construct meaning embedded in data. Paradigms are thus important because they provide beliefs and dictates, which, for researchers in a particular discipline, influence what should be studied, how it should be studied, and how the results of the study should be interpreted. The paradigm defined my philosophical orientation and, as I stated in the conclusion to this section, this has significant implications for decisions made in the research process, including choice of methodology and methods. And so, a paradigm tells me how meaning will be constructed from the data I shall gather, based on my individual experiences, (for example, where I am coming from). It was therefore very important, that when I wrote my research proposal for this study, I clearly stated the paradigm in which I located my research.

A paradigm can also be defined as a mental model or a framework of thought or belief through which one interprets the reality. In this research, the paradigm reflects my abstract beliefs that guide my interpretation of reality and it also helped me to grasp the clear picture of the research under study. Furthermore, Tuli (2010) states that a researcher is undertaking their research journey under the framework of some paradigms, whether they are aware of it or not. In this study, I was clear about which paradigm to use; choosing my methodology, methods and research design become easier to decide (Mackenzie and Knipe, 2006). This is a conceptual structure the researcher gets clarity about the methodological aspect of the research problem to decide which methods of data collection and data analysis are to be used (Kivunja and Kuyini, 2017). According to Tuli (2010), a paradigm is established because within it there are ways of viewing reality and knowledge. Therefore, the basic tenets of the paradigm suggest particular ways of defining, refining and presenting knowledge. According to Atieno (2009), a paradigm can be understood either as an approach or a design, so, there are some paradigms which are favourable for quantitative approaches while there are others which are favourable for qualitative approaches and yet there are some other paradigms which are favourable for both approaches known as mixed method approach (Mackenzie and Knipe, 2006). The selected paradigm, Constructivism, was discussed in Chapter 1 and a further brief discussion follows below.

3.2.1 Constructivism

In Table 3.1, the basic beliefs associated with this paradigm are identified by Guba and Lincoln (1994) and adapted by Mertens (2010).

Table 3. 1 Basic Beliefs Associated with Constructivism

Basic Beliefs	**Ontology**	**Epistemology**	**Methodology**	**Associated labels**
Constructivism	Multiple, socially constructed realities	Interactive link between researcher and participants. Values made explicit	Qualitative, Hermeneutical, Contextual factors are described	Qualitative, Naturalistic, Hermeneutic, Interpretivist

Source: (adapted in part from Martens, 2010, p.11)

One of the fundamental principles of constructivism is that I am a fundamental part of the research process. Constructivism recognises that one's background "shapes interpretation… to acknowledge how their interpretation flows from their personal, cultural and historical experiences" (Creswell, 2003: pp. 8-9). My intent was to make sense of (or interpret) the meanings participants (teachers and students) have about the research under study. Rather than starting with a theory (as in post-positivism), inquirers generate or inductively develop a theory or pattern of meaning. Both constructivism and interpretivism also recognise the importance of context (Smith, 1996, Creswell, 2003). I used an inductive approach where meaningful themes and theories emerge from analysis of data (Glaser and Strauss, 1967). Qualitative action researchers do not seek generalisability. Their main objective is to record as accurately as possible the unique experiences of a person, people, event, or situation (Stake, 2010), which Table 3.1 clearly identifies. Credibility, transferability, dependability, and confirmability are fundamental constructs associated with this tradition. The kinds of methods employed in higher education qualitative studies include documentary analysis; comparative studies; interviews; surveys; observation studies; case studies and conceptual analysis (Trowler, 2012).

In this study, data were collected from multiple sources, such as teaching staff involved in school access provision, as well as students who are the 'users' in this institutional provision. These data instruments are congruent with a constructivist paradigm. In addition, to answer the research questions in this study consideration must be given to the impact of the wider socio-economical, historical, and cultural context.

3.2.2 Interpretivism

Schwartz-Shea and Yanow explain that "[r]esearch design is about making choices and articulating a rationale for the choices one has made" (p. 2). Their emphasis is directed toward the "concepts and processes in interpretive empirical research design, and the methodological issues they raise, looking across methods of generating and analysing data" (p. 9). To accomplish this aim, the defining characteristics, questions and concerns of this research perspective are placed alongside those of positivist-informed approaches (both quantitative and qualitative), which successfully bring into focus the constitutive elements and rhythms of designing interpretive research. Interpretive research was vital to this investigation, as the aim was to specifically examine the implementation of intervention provision and to demonstrate a positive approach about learning mathematics being developed to reduce GCSE mathematics student underachievement. In particular, the research aimed to explore student participants' views on interventions to support their GCSE learning; thus, it was research based around a humanistic approach. The research was underpinned by the associations that participants developed, and their interpretations and understandings of different meanings of engagement with intervention (Burr, 2015).

Through engaging with the data, I came to understand that there were many ways that participants thought about, and reacted to, different understandings of intervention; I came to acknowledge that intervention was socially constructed in many ways. An interpretative research method could be useful in this research because by drawing on the everyday meanings of the participants it enables the researcher to capture the variety of ways the interventions were understood. Therefore, interpretative research aligns with the theory of social constructionism, because it is embedded in the context of fluid social interactions and recognises that individuals create meanings and make sense of their world through continual social interactions in their contexts (Picardi and Masick, 2014) in this case secondary school mathematics classes.

The assumptions behind interpretive research are different from those of other approaches. The primary ontological assumption is that our reality is subjective; that is, the world is discovered through people's opinions and judgements (Wegerif, 2008). By assuming and accepting that the individuals participating in the research have their own realities, I had to assume and accept that more than one factor could influence the social parameters of the participants' responses in terms of creating meaning of the interventions in the study. The epistemological assumptions for interpretive research methods are about individuals' beliefs (Friedman, 2003). Interpretivists believed there is no specific pathway to the knowledge; rather, that knowledge was created by participant's interpretations, and so reflected both the human experience and the context. Hence, the theory of social constructionism has been applied as the theoretical lens for this research. Participants cannot separate themselves from what they know; it is not all about truth, prediction and control, but participants developing their meanings and understandings of different concepts through social interactions (Burr, 2015). These epistemological assumptions form a sustained foundation for this research because all of the interventions were based on learning in a group rather than as individuals. Consequently, this philosophy emphasises qualitative analysis over quantitative analysis which will be discussed in the next section.

3.3 Rationale for Action Research Using a Qualitative Approach

This section looks at the overachieving theoretical considerations for using a qualitative action research method. In researching the different approaches that could be used to carry out this research, two definitions of action research suited the nature of the research because my epistemological beliefs about knowledge and the role of teachers to improve outcomes in GCSE mathematics with a specific focus on students who are predicted to just miss out on a 'good GCSE pass' which is defined as a 'grade 5' in the new scale or a 'grade C' in the old scale. Furthermore, to develop the participating teachers' professional growth, including mine, was important as Hargreaves (1992) explained that the quality and flexibility of teachers' classroom work is closely tied with the course of his or her professional growth, the way he or she develops as a person and as a professional. McNiff (2010: p.24) stated that:

> action research is always to do with improving learning, and improving learning is always to do with education and personal and professional growth, many people regard action research as a powerful form of educational research.

Cohen, Manion and Morrison, (2018: p.226) define action research as "a small-scale intervention in the functioning of the real world and a close examination of the effects of such an intervention" and because this study was about interventions the action research was the pathway most suitable as Johnston-Wilder et al (2013) describes the ways in which students can develop positive approaches to the learning of mathematics that give them strategies to overcome any difficulties they may face. Furthermore, it draws on a methodology that 'worked' for the researcher; this proposal is equivalent to Altrichter and Posch's (1989: p.29) suggestion, "what's good for the practice is good for research" and because I was focused on developing better practice in working with colleagues and students, I decided to carry out my research as a teacher researcher using action research. The next section outlines the action research approach I used in this study.

3.4 The Action Research Approach

The concept of Action research is credited to Kurt Lewin (1946 and 1952) in the United States (US) and was first expressed in the work of the Tavistock Institute of Human Relations in the UK (Rapoport, 1970). Dick (2002) defines action research as a flexible spiral process which allows action and research to be achieved at the same time, where action is about change or improvement and research about understanding or knowledge. It emphasises group decision and commitment to improve organisational performance (McTaggart, 1991). This distinctive feature requires that "those affected by planned changes have the primary responsibility for deciding on courses of critically informed action which seem likely to lead to improvement and for evaluating the results of strategies tried out in practice" (McTaggart, 199: p.170). According to the central tenet of Argyris' interpretation of Kurt Lewin's (1946) concept, action research involves change experiments on real problems in social systems that focus on a particular problem with a view to providing solution to the client's system (Argyris et al., 1985). Although students are not clients, they are the focus of the work of schools so solving problems of underachievement is the problem of this study.

Gummesson (2000) has enumerated the characteristics of action research from a management perspective; these characteristics involve taking action and pursuing dual goals of solving organisational problem and contributing to the body of scientific knowledge, for example, research in action. It also involves the iterative process of the researcher, in collaboration with others, such as students and teachers, as participants, continuously adjusting to new information and new events as they unfold. It involves developing holistic understanding, recognising the complexity of organisational systems (Stacey, 2011), for example, in the training consultancy industry and the healthcare industry where action research has gained ground over the years (Bate, 2000). In the secondary school education system, the level of complexity around predicted GCSE grades and working toward ensuring all students achieve to their highest ability is just as complex an organisations system as any found in industry or healthcare.

Action research can use quantitative and/or qualitative methods of data generation but quantitative methods have limitations in providing in-depth explanations of intervention evaluation phenomenon (Patton, 2002). Qualitative research methods are more likely to provide rich insight and in-depth understanding of the experiences of the individuals and groups as well as the meanings they attach to intervention evaluation process (Patton, 2002). Action research also requires the level of thorough pre-understanding of the organisational environment, structures and systems in which the intervention is situated, whether it is a single classroom or a year level within a secondary school, such as Majac Secondary School in this study. It calls for explicitly stating the theoretical underpinnings of these pre-understandings (Coghlan and Brannick, 2010). The process for dealing with the conflict of role duality in first-, second- and third-person practice suggested by Coghlan and Brannick (2010) will serve as a guide for me. Going by this guide, I tried to to catch internal responses to conflicting demands and deal with them right from the time of obtaining consent from the participants. I also used the opportunity of the very first one-to-one semi structured teacher interview and focus group interview to negotiate my role with every participant represented. Finally, I linked my experience of insider-outsider role with relevant theory. Action research is conducted in real time as an intervention to promote reflection and organisational learning and assurance of quality in the underlying research philosophy of me, the researcher (Chapter 1, section 1.13). This is important because action research is judged by the criteria of its own terms and not in terms of positivist science (Coghlan and Brannick, 2010). In positivist research, the quality test of reliability refers to replicability of research findings. Internal validity refers to correct mapping of the phenomenon with findings while external validity refers to generalisability of findings (Denzin and Lincoln, 1994).

The intended change involves inquiry and seeking to increase understanding of individuals through participation of relevant stakeholders in action to challenge the status quo. As Moore (2007: p. 30) emphasises, “You don’t do action research in order to simply maintain the status quo”. The improvement of the problem situation is intended to simultaneously contribute to new knowledge in social change. This is the kind of action research long advocated by Rapoport (1970: p. 510) that “seeks to optimise the realisation of both the practical affairs of man and the intellectual interest of the social science community”. In this respect, action research perhaps stands as the most appropriate approach to engage in first person, second person and third person research, all of which would be desired for an intervention focused on organisational change. It can be reasoned that implementing the intended change to mathematical interventions through action research stands to benefit the academic and professional development of the researcher as a scholar-practitioner, benefit the participants (students and teachers) in their day-to-day practices and benefit Majac Secondary School’s mathematics department in improved GCSE intervention effectiveness. At the same time, it will generate new knowledge to other secondary schools. Kemmis and McTaggart, (1988: p.5) state:

> Action research is a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situation in which these practices are carried out.

As well as highlighting the basis of personal experiences and aspirations this quote emphasises that action research is both reflective and collective and that it should be concerned with the rationality and justice of social situations, a theme further examined by Carr and Kemmis (1986), in which they promote a ‘critical’ form of action research concerned with enhancing social justice and actively tackling inequality. These aspirations for participation, change and improvement are meant to be achieved through a common process, the action research cycle, which will be discussed in the next section.

3.4.1 The Action Research Cycle

Action research has historically been viewed as cyclical in nature (Mertler and Charles, 2008). That is to say, whereas action research has a clear beginning, it does not have a clearly defined endpoint. Ordinarily, researcher practitioners design and implement a project, collect, and analyse data to monitor and evaluate the project's effectiveness, and then make revisions and improvements to the project for future implementation. It is possible that the project would then be implemented again when the effectiveness of the revisions would be monitored and evaluated, with new improvements developed for the next phase of implementation. Trip (2005) suggests any action research project should begin with a reconnaissance. This stage allows the researcher to find out more about the starting points and needs of the research participants. The next step is to carefully plan the first intervention based on the findings during the reconnaissance. The intervention is implemented, and observations made of the outcomes. These observations can take a variety of different forms. Once these observations are made, the researcher reflects on what has happened and uses these reflections to plan the next cycle. Although I refer to the original model, the work of Kemmis and McTaggart (1992) expanded on the definition of action research describing it as a professional practice development tool, emphasising the importance of all of the participants having a voice when undertaking the research, especially in the review stage. For the purpose of my research, this meant that when I reviewed the success of the intervention, I needed to include a collection of the students' own reflections.

The cycle of action research, widely known in the broad field of educational research, was seen to be gaining increasing currency in intervention (Burns 2005a, Burns, 2005b, Mann, 2005). One of its best-known representations, based on the spiral concept of Lewin's original work, is by Carr and Kemmis (1986), who stated that one crucial step in each cycle consists of critical reflection. The researcher and others involved first recollect and then critique what has already happened. The increased understanding which emerges from the critical reflection is then put to good use in designing the later steps. Figure 3.1. indicates that the early cycles are used to help decide how to conduct the later cycles. In the later cycles, the interpretations developed in the early cycles can be tested and challenged and refined.

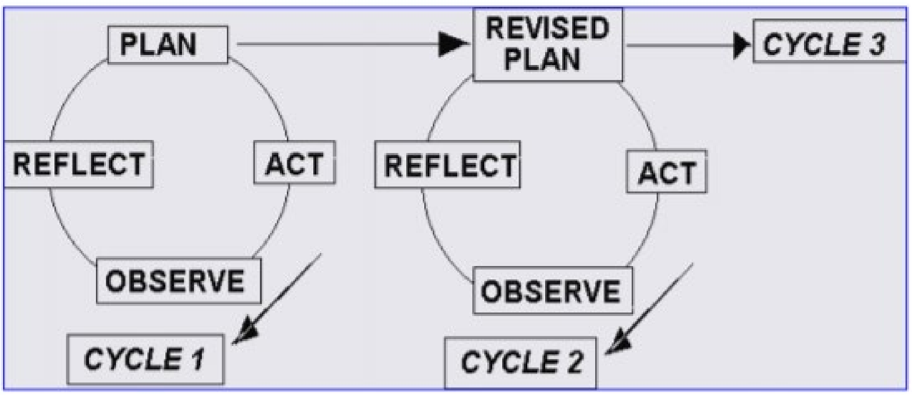


Figure 3. 1 Cyclic Action Research Process

Lewin (1946: p.38) stated that:

[Action research is] …composed of a circle of planning, executing, and reconnaissance or fact finding for the purpose of evaluating the results of the second step, and preparing the rational basis for planning the third step, and for perhaps modifying again the overall plan.

These cyclic representations should not be seen as definitive of the AR process; many action researchers perceive a more complex series of steps (Burns, 2005b) and to specify strictly detailed procedures would limit the potential for contextual variability that is a major strength of action research (Hopkins, 2002). Nevertheless, action research methods can be responsive to the situation in a way that many other research methods cannot be, at least in the short term. Therefore, AR will usually, though perhaps not always, be cyclic in nature and in the interest of rigour, each cycle will include a critical reflection. In most instances it will also be qualitative and participative to some extent. In the current research study, given its longitudinal nature, I would be able to see the effects of a first intervention to determine what happened next.

3.4.2 Action Research as Social Construction

The central idea of social construction is that whenever we employ words or other symbols to refer to objects in our social world, we are constructing them, quite literally, as meaningful social objects that we can take account of in our actions (Fulcher and Scott, 2003). There are several forms of constructivism/ constructionism and the common thread between all forms of constructivism is that they do not focus on an ontological reality, but instead on the constructed reality (Weber, 2014). Constructivism is part of wider framework of symbolic interaction theory (Goffman, 1956; Blumer, 1969) which is related to the sociology of action. Symbolic interactionism is the theory that explanations of order and change come from the observations of everyday life and the interactions between people, rather than from large scale social forces and natural laws. Symbolic interactionism aimed to uncover processes of communication and interaction that allowed people to make sense of their social world and for them to create or construct the structures that structural functionalists treated simply as social facts.

In this study the social constructivist view builds on the belief that the participants produce knowledge socially and culturally, and also that learning is a social process (Kim, 2001). Accordingly, Richardson (2003) notes that the focus of social constructivist pedagogy is “the consideration of how individual learner learn to ways of facilitating that learning, first in individual learners and then in groups of learners” (p. 1626). During the after -school Phase One intervention session the students were engaged as working in small groups, but they also had the opportunity to work independently to develop their own learning and progress in mathematics. Scholars (such as, Karagiorgi and Symeou, 2005; Khine, 2006; Baviskar et al., 2009; Arends, 2012; Pitsoe and Maila, 2012) debate various characteristics of social constructivist pedagogy, but they agree that it:

- Acknowledges the multiple representation and complexities of worldviews from a broad range of knowledge sources in the cultural context.
- Requires active collaboration and cooperative, uncompetitive and autonomous environments for deep learning through which individuals’ beliefs and background understanding are co-constructed in group settings.
- Demands creativity and reflectivity in the teaching and learning process.
- Depends on the context and content of knowledge construction, authentic learning context.

Taylor (2009) identifies six interdependent key characteristics of the social constructivist pedagogy: (1) individual experience, (2) critical reflection, (3) dialogue, (4) holistic orientation, (5) awareness of context, and (6) authentic practice. Using Taylor's view, I engaged the students in critical reflection by utilising their education background, but also in the use of authentic learning activities to motivate the students through interventions, such as Phase Two, the mathematics camp. My engagements with students were in utilising features for knowledge construction practices should mean they are considering the social constructivist lens.

3.4.3 Action Research Using a Qualitative Method Approach: Theoretical Context and Rationale

Snape and Spencer (2003) note that the advent of qualitative research in social studies was signalled by dissatisfaction with the rigid and distant methods flagged by quantitative research perhaps more associated with the 'scientific' tradition. Although qualitative methods have been unfairly accused of being less objective, it is true that all research methods, whether qualitative or quantitative in nature, are inherently biased, regardless of techniques and roles as discussed in Monahan and Fisher (2010). In this sense the researcher needs to be inside the world to be studied for its social construction (Denzin and Lincoln, 2005; Hammersley, 2007). At some point, there is always a human being behind the research process, and human beings cannot detach themselves from their personal socially constructed history. We see what we want to see and "history and fiction, reality and desire, are blurred" (Brown and Jones, 2001, p.71). My role as researcher and educator in this research project meant that I was inside the world to be studied and was also viewing the actions research cycles from two somewhat merged or blurred viewpoints.

Snape and Spencer (2003) indicate that as researchers worked to refine their roles in terms of closer relationships, that is, "walking shoulder to shoulder with ordinary people" (Swantz, 2008: p.31), action research emerged. Its origins are often credited to John Dewey, social psychologist Kurt Lewin, and Lawrence Stenhouse. It appeared as a way in which research findings were directly fed back into the environments from which they were generated to enhance reflective practice in collaboration (Burns, 2005b; Mann, 2005; Somekh, 2006; Elliot, 2009). For the action researcher, reality is "socially constructed" (Koshy, 2010: p.23) with the participants.

The research aims set out in Chapter One are those that will best provide insight to this research study. The overall aim of this research is to specifically examine the implementation of an intervention programme and to demonstrate a positive approach being developed to reduce underachievement. Miles, Huberman and Saldana (2014) have summarised the strengths of qualitative data in terms of realism, richness and a longitudinal perspective, locating the meaning of experience within the social world; in other words, placing the phenomena within their context. This, it seems, is crucial in seeking to explain phenomena and to generate theory.

Generation of theory is a key feature of qualitative research (Gummesson, 2005). In contrast, positivist, and perhaps quantitative approaches, aim to test theories specified at the start of a study (Bryman and Bell, 2007). Furthermore, generalising is a common aim with quantitative research (through statistical sampling), which is not the case with qualitative research (Silverman, 2013). This is not to imply that qualitative research cannot be used to test theory, or indeed, that it cannot be combined with quantitative methods. As Silverman (2013) notes: "Qualitative research can mean many different things involving a wide range of methods and informed by contrasting models" (p. 14). Similarly, quantitative research can be used for theory generation (Robson, 2002). The point is, perhaps, that there is no right or wrong, no one approach that is the 'best'. The issue is more that the choice of approach should fit the research aims and questions, the purpose of the study, as well as the conceptual framework within which the researcher operates (Silverman, 2013). As Goulding (2002) has noted, though, researchers always aim to reduce subjectivity and to apply academic rigour to any study. In addition, there is the alternative view, held here, that a subjective position is one of the features of qualitative research; the researcher is a measurement device, and is viewing the phenomena from the inside (Miles et al., 2014).

However, despite these shortcomings, qualitative research becomes prominent in educational research as it is a regular accompaniment with quantitative data analysis to which reports of standard setting are generally confined (Manias and McNamara, 2015). Moreover, generalisability seems not to be a problem as Darlington and Scott (2003: p.18) pointed out that, "If one considers the unit of attention as the phenomenon under investigation, rather than the number of individuals, then the sample is often much larger than first appears". Thus, in the current study, the number of interactions or contacts investigated would have been larger than the individuals or students involved. Moreover, Labaree (2004) suggested that no educational research (either quantitative or qualitative) ought to be regarded as generalisable, because too many contextual variables can shape the findings. For example, if a student is unable to demonstrate enough proficiency in reading or mathematics, quantitative measures, such as, test scores may indicate that the teacher is to be condemned. However, the test scores fail to consider the classroom environment, students' home life, and other crucial factors. Donmoyer (2012) argued that the qualitative researchers can tell the policy makers what works because qualitative research provide the thick description necessary to understand research about a persons' lives, lived experiences, behaviours, emotions, and feelings as well as about organisational functioning, social movements, cultural phenomena, and interactions between nations. Within a qualitative framework, and an interpretivist stance, this thesis is concerned with identifying the impact of interventions on students and teachers when students underachieve and disengage in mathematics.

Qualitative data sources ensure that a range of perspectives are included in this study. Semi-structured one-to-one teacher interviews and focus group interviews with students, opinions, and feedback (micro level) on intervention provision were gathered as were classroom observations (meso level) providing further evidence thereby increasing the validity (which will be discussed in sections that will follow) of this research.

For the purpose of the research objectives, action research is the most appropriate methodology to answer the research questions for this study. In conclusion, a constructivist paradigm incorporates the ontology, epistemology, and methods best suited to the research stance and questions in this study, which will be discussed later in this section.

3.5 Aims, Objectives of Study and Development of Research Questions

This study focuses on examining the implementation of intervention provision for GCSE students in mathematics. Therefore, the purpose is to develop a comprehensive classification of the types of use of research indicators which can be used in qualitative studies. The classification is derived from the information on research indicator use given in the literature in the field of mathematics underachievement. I illustrate the different categories; “explanatory” and “descriptive” which, as Babbie (2010: p. 94) writes, seek to answer questions of why and how.

With reference to the development of the research questions in this study, Creswell (2012) believes that, at the start of a research study, questions should be reduced to a single principal question and several sub-questions. In this study, the central research question is, *given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?* Based on a review of the relevant academic and policy literature in the field and guided by the overarching research problem, more specific secondary research questions have been developed to guide the analysis of this study. These research questions are divided into four distinct yet interconnected layers:

International / Comparative level (Macro Level Analysis)

(1) Why do students underachieve academically when the ability to achieve is present?

National Level (Macro Level Analysis)

(2) What were the key participants' perceptions of their successes and failures in the study?

(3) Why is it important to empower able underachievers?

Institutional Level (Meso Level Analysis)

(4) What factors contribute to their psychological and academic needs?

Individual Student Level (Micro Level Analysis)

(5) How can strategies and techniques help enhance student performance?

Some general epistemological issues will be considered next which provide a justification for the stance taken in this study.

3.6 Situating the Researcher in the Context of the Research

As noted earlier in this chapter, epistemologically, this study takes an interpretivist stance. An integral feature of this particular stance is that the researcher needs to be situated within the research context and formally acknowledge that the research is influenced by the researcher's background, experience and values and that it is not possible to isolate the researcher from the research. Prior to working in Higher Education, I worked as an Assistant Headteacher and a mathematics teacher in charge of raising standards across Majac Secondary School. I had been working in the area of mathematics teaching, progression and achievement since 2001 in the UK and since 1994 in South Africa.

3.7 Context of the Study

Majac Secondary School (pseudonym) located in an urban London Borough, opened in 1962 as the Majac Boys Secondary School, a single-sex school, taking over the senior boys of Bowmont Road School (pseudonym) when it ceased to cater for the full age-range, as well as the boys from Riverjoy Technical School (pseudonym). From the late 1960s to the mid-1980s it was called Majac Boys Secondary School, the name being changed to Majac School on the admission of girls in 1985 for the first time.

In 2010 under a central government public works programme entitled Building Schools for the Future, the original mid-20th century design school buildings on the Bowmont Road site and its attached hardcourt sports fields of an athletics field, football pitch and tennis courts, were demolished, and a new school building and sports ground at a cost of £36 million. The new school was initially designated as a 'Specialist Visual Arts College' (Arts Colleges were introduced in 1997 as part of the now defunct Specialist Programme in the United Kingdom. The system enabled secondary schools to specialise in certain fields, in this case the performing, visual and/or media arts), but was reclassified to Academy status in August 2012. An Ofsted inspection in February 2014 rated the school as ‘good’, stating that students were making ‘strong progress’, and that the ‘teaching standard was good’.

The age range at Majac Secondary School was 11-18 with a total enrolment in 2013-2014 of 1122 with a school capacity of 1350, indicating it is a large school. There were 87 teachers of whom 12 were mathematics teachers. The mathematics department of 12 teachers consisted of a deputy headteacher, an assistant headteacher, a HoD, a second in department lead teacher, a KS 3, KS 4 and KS 5 lead teacher and the remaining five teachers were teachers without any responsibility in the Majac Secondary School mathematics department. I was an assistant headteacher in my eight year of teaching mathematics at Majac Secondary School. As assistant headteacher, I was responsible for raising standards across the school. The mission statement of the school indicates that 'In the Majac Secondary School community, everything matters, at all times. Plan, challenge, motivate, achieve'. Therefore, as raising standards leader (RSL), I needed to ensure that students make excellent progress across Majac Secondary School curriculum and work with groups and individuals to ensure that they are challenged, motivated and the barriers to progress are removed. In mathematics I worked with students on a one to one, or as part of a small group over a period time (a half term or term).

The research took place in confined spaces (such as, the school and an activity centre) to include information about participants' lives from the participants themselves and notes from the researcher (Latif, Boardman, and Pollock, 2013). The disadvantage of these settings is that it became harder to control external factors (Muijs, 2008). For example, according to Rockoff (2004), the type of teacher that a student has significantly affects academic potential and/or achievement. The qualifications of a teacher do not necessarily rest within his/her credentials. The collegiality, drive, and willingness of a teacher to ensure that his/her students are successful are associated with students' academic achievements (Marzano, 2003). Providing students with clear objectives and expectations increase student academic achievement.

I worked with the HoD mathematics, to monitor students' learning, effort and achievement in GCSE mathematics. Detailed discussions took place in terms of progress and discussion of any barriers to learning. From 2013-15, the RSL attended weekly pastoral meetings within SLT to ensure that key issues emerging in curriculum could be discussed at a pastoral level to ensure a joined-up strategy. A targeted review meeting in April 2014 with key Year 11 mathematics parents was a new initiative emerging from this alignment of pastoral and curriculum information. The RSL produces information for all departments to illustrate what this actually means in terms of the average grade for the department or class required in Year 11 and how many grades would need to change to achieve this, either at whole school, department, or individual class level. Building relationships (Rader and Hughes, 2005) with key Year 11 students through assemblies, presence and meetings with students and parents aimed to reduce barriers and enhance engagement (Sullivan, McDonough and Harrison, 2004), resilience and outcomes.

3.8 Sampling

Research quality, as well as being determined by the appropriateness of the methodology and instrumentation, relies on the suitability of the sampling strategy (Bryman, 2008, Babbie, 2010; Mertens, 2010). Therefore, in this study, I engaged in purposive sampling which is defined by Denscombe (2008: p.182) as "participants are selected on the basis of some personal attribute that is relevant to the purposes of the research". In this research study the sample for the interviews has been chosen from students enrolled at Majac Secondary School at the start of Year 7 and teachers who were teaching Year 7 in September 2012. Purposeful sampling is a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources (Patton, 2002). This involves identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Cresswell et al., 2007). In addition to knowledge and experience, Bernard (2002) and Spradley (1979) note the importance of availability and willingness to participate, and the ability to communicate experiences and opinions in an articulate, expressive, and reflective manner.

3.8.1 Sample Size

Holloway and Wheeler (2002) assert that the sample size does not influence the importance or quality of the study and note that there are no guidelines for determining sample size in qualitative research. Guest, Bunce and Johnson (2006) emphasised the need for numerical targets for sample sizes of interviews. Furthermore, Crouch and McKenzie (2006) propose that fewer than 20 participants in a qualitative study help a researcher build and maintain a close relationship and thus improve the 'open' and 'frank' exchange of information. This process can help mitigate some of the bias and validity threats inherent in qualitative research.

In this study, the total number of students was 10. As there were two cohorts (A and B) in Majac Secondary School, and each cohort was divided into five sets in mathematics, one student per class was chosen to be representative of each set in the mathematics cohort. The list was given to the HoD mathematics, the deputy head teacher and mathematics staff for their input into how the students should be selected.

I worked in conjunction with the mathematics staff in choosing the participants, based on their academic performance to establish which students were underperforming from their KS 2 data and their performance in the transition test from primary to secondary school.

As noted by Creswell (2012: p.193), "the value of qualitative research lies in the particular description and themes developed in the context of a specific site. *Particularity* rather than *generalizability* is the hallmark of qualitative research".

3.8.2 Sampling Procedure

Sampling of the participants was done as follows (Cresswell et al., 2007):

• *Identification:* assistance was sought from the HoD and mathematics staff to identify potential participants to give their input into which students should be selected based on academic performance at KS 2 and the entry test in Year 7;

• *Selection*: possible participants were selected after the pre-selection of participants according to the following criteria: (a) their national curriculum level on entry (b) their performance in that specific set they were placed in and (c) their teacher assessment in secondary school;

• *Agreement:* the research project was explained to the prospective participants who were on the short-list, and they were asked personally if they wanted to take part in the research; I received written approval from the students and their parents;

• *Data collection*: Focus Groups - The mathematics staff and I selected the 10 prospective participants for the focus group interviews; and,

• In the event of a student withdrawing, the mathematics staff was asked to refer other participants with similar academic abilities and performance.

3.8.3 Study Participants

Table 3. 2 Student Participants' Data Collection Methods

Student Name (Pseudonym)	**Classroom observations**	**Focus Group interviews**
Ray	✓	✓
Logan	✓	✓
Dakota	✓	✓
Hayden	✓	✓
Sam	✓	✓
Gray	✓	✓
Alex	✓	✓
Julian	✓	✓
Brook	✓	✓
Roan	✓	✓

Student participants in the focus group interviews included, three boys and two girls, in each set of five, ranging in ages from 11-12 years old in Year 7 and 13-14 in Year 9.

Table 3. 3 Teacher Participants' Data Collection Methods

Teacher Participant (Pseudonym)	Classroom observations	Semi-structured one-to-one interviews
Ms. Hanekom	✓	✓
Mr. Smith	✓	✓
Mrs. Van Turha	✓	✓
Mr. Tromp	✓	✓
Ms. Adams	✓	✓

Teacher participants included two men and three women, with ages from 25–48 and individual classroom experience ranging from 2 to 7 years.

In this study, a manageable professional inquiry of the classroom teachers which enabled the study of classroom strategies and actions for change (Nicol, 1997). The aim was for students to develop an inquiry stance (Cochran-Smith and Lytle, 2009) toward learning wherein they acquire knowledge for learning throughout their mathematics studies instead of striving to obtain it all in one term of their GCSE. This goal was articulated to students with the following objective: take an inquiry stance toward the learning of mathematics, which means studying one's own learning in order to build knowledge through examination and reflection of the events happening in the classroom.

The methodology employed in this study comprises a review of the pertinent literature, policy documentation, institutional strategy, and policy statements as well as qualitative semi-structured interviews and focus groups. Details of data collection below provides a summary of the methods of data collection across the two case sites (Majac Secondary School and Riverview Activity Centre).

3.9 Data Collection Methods

I considered what data collection methods would give the greatest insight into what was actually happening in the classroom, whether changes are superficial or lasting and whether learning is actually improved. Thus, my decision to use qualitative methods approach depended on the research questions. In the next section I discuss the organisation of my study.

3.9.1 Organisation of the Study

The study happened in two phases. Phase One consisted of three data collection methods: semi-structured one-to-one interviews with teachers, classroom lesson observation and student focus group interviews. Phase Two of the analysis began after Phase One has been completed and consisted of semi-structured one-to-one interviews with teachers and student focus group interviews.

3.9.2 Phase One and Two Schedule

Table 3. 4 Stages of Data Collection and Analysis

Action	Date
Letters sent to prospective participants (students and teachers)	December 2012
Phase One: Initial Data collection and analysis	
Ten teacher participants recruited	January 2013
Initial focus groups interviews (Year 7 students)	June 2013
Initial semi-structured one-to-one teacher interview	June 2013
Classroom observations	June 2013
Focus group and teacher interviews and data transcribed and analysed	August 2013– April 2014
Six weeks Intervention programme	April–May 2014
Phase Two: Final data collection and analysis Date	
Final focus group interviews with students (Year 9)	July 2015
Final semi-structured one-to-one teacher interviews	July 2015
Focus group and teacher interviews and data transcribed and analysed	August – December 2015
Weekend away Intervention (Year 11) 10 student participants)	March 2017
Post Phase Two Intervention -Mathematics camp-Questionnaire with students	March 2017

Patton (2002: p.244) suggests, "By using a combination of observations, interviewing, and document analysis, the fieldworker is able to use different data sources to validate and cross-check findings". Combining data sources to validate and crosscheck findings triangulates the data and increases validity as the strengths of one approach can compensate for the potential weaknesses of another (Maxwell, 2005; Silverman, 2015). The data collection points, above, will be discussed in the sections that follow.

3.9.3 Teacher Semi-Structured Interviews as Research Methodology

One of the secondary research questions in this study is: *how can strategies and techniques help enhance student performance*? Therefore, it was necessary to gather opinions and perspectives from teaching staff (micro and meso levels) associated with the students (micro level). Following a review of methodology literature, (for example, Bryman, 2008; Babbie, 2010; Mertens, 2010), it was decided that semi-structured interviews were the most appropriate instrument. As a research instrument, interviews have several advantages. As Silverman (2015: p.44) stated, the aim of the interview was to gain "an 'authentic' understanding of peoples' experiences". First, interviewing offers an opportunity to access a wide breadth and depth of information and second, a relationship with the interviewee is created by the very process of interviewing and, therefore, a degree of flexibility can be allowed as part of this method (Mertens, 2010: p. 352). As with all instruments of research, there are some disadvantages associated with this method. Interviews can, for example, be time-consuming, can be expensive, if for example, travel is required, analysis can be difficult and the process of interviewing can bias the respondent's response (Mertens, 2010: p. 352). Furthermore, Silverman (2015) stated that analysis of an interview is linguistic in character including paralinguistic features such as facial expressions, eye movements and so on. For this reason, the process of data analysis needs to take into account some notion of how accurate the account is. Taking these factors into account, it was decided that the advantages outweigh the disadvantages, and that interviewer bias could be minimised by using a semi-structured format with a four-point interview schedule (McCracken, 1988: pp. 24-25). Figure 3.2 details the questions asked for the teacher semi-structured interviews in this study.

1. What do you think motivates students to learn?

2. What motivates those students when do you think they learn well?

3. What are some of the things you have tried to do to get through to these students?

4. Now, you have said that, and you know that, some of the students are hard to reach at times, even if you provide fun activities and so on for them. What do you think makes it so hard to reach these students?

5. Now think of a good educational experience. It can be in school or outside of school but think of a time when you had an aha feeling, when everything fell into place. Maybe you could finally do something you had been struggling with or something finally makes sense to you. Maybe it was when your art teacher finally taught you how to mix paint and get primary colours or maybe it was when your mum or your dad taught to tie your shoelaces. So, whether it was inside of school or outside of school, think of a time that you had a good educational experience. Can you briefly describe that to me?

Figure 3. 2 Questions for Teacher Semi-Structured Interviews

The teacher semi-structured interview was employed in this study as it offered a different mode of communication and arena of expression to the student focus group discussions.

3.9.4 Procedures for Interview

Instruments used to conduct the 10 semi-structured teacher interviews included an information letter, a copy of which is included in **Appendix A** (Teacher / Student Information Sheet) and **Appendix B (**Teacher Consent Form**)**. The purpose of these in-depth interviews was to first critically examine how teachers perceive the teaching of mathematics and how they engage with students in their classes and, second, to observe how such teaching fit in to existing strategic approaches at meso and macro levels. Face-to-face interviews were conducted in the teachers' places of work, which was Majac Secondary School. To facilitate accurate transcription, interviews were recorded. Interviewing proved worthwhile as rich data emerged.

Sincere gratitude is particularly expressed to the school that provided me with access and facilitated me with compiling lists of people who would be most relevant to interview, as without their co-operation my research would not have been possible.

3.9.5 Non-Participant Observations (Student and Teacher Participants)

Non-participant observation is a relatively unobtrusive qualitative research strategy for gathering primary data about some aspect of the social world without interacting directly with its participants. I engaged in these non-participant observations as I had limited or no direct access to the students or the teacher participants. Angrosino (2012: p.166) discusses that observation is "well-established and most frequently used for classroom research", and Punch and Oancea (2014) also comment that observation has been widely used in educational research. Cohen, Manion and Morrison (2011: p.456) point out that "observation's unique strength" is its potential to produce "valid and authentic data" because it focuses on the collection of data collected directly by looking at real situations. Cohen and Mannion (2015) explain that highly structured observation is when the phenomena being observed for and recorded is planned in advance. In addition, Moule and Goodman (2009) suggest that strengths of observation for data collection include events that take place in real time and are natural real-life occurrences; however, weaknesses that have been noted include how time-consuming and intrusive they can be. Furthermore, one of the advantages of using classroom observations is that they offer the researcher an opportunity to gather 'live' data from naturally occurring situations (Cohen et al., 2015). This means that observations enable researchers to study behaviour as it occurs. Another advantage of observations is that they allow the researcher to collect data first-hand, thereby preventing contamination of the factors standing between him or her and the object of research (Nachmias and Nachmias, 1996).

I observed teacher participants and their students during teaching sessions, with a focus on how mathematics learning was conveyed and perceived by the students. I used a non-participant approach, which Walliman, (2016) explains as the researcher assuming detachment with the intention of being ignored by those being observed, also referred to by Cohen, Manion and Morrison (2011: p.459) as when the researcher "adopts a passive, non-intrusive role". Punch (2009: p.154) refers to non-participant observation as being "pure or direct", which is when the researcher observes but does not "manipulate nor stimulate" those being observed. As Menter et al (2011) described non-participant observation as observing and recording whilst not contributing or interfering in the event, I was present in the classroom but not engaged or involved with the activities. Indeed, Kumar (2011) states clearly that this form of observation is about not being involved in the group activities, but rather paying attention to what is seen and heard and then making some conclusions. Further, Check and Schuh (2012: p.194) refer to this approach as "overt observation". Green and Thorogood (2014: p.155) also support this view by stating "non-participant methods … include studies in which the researcher is present to collect the data but does not interact with participants".

For the lesson observations, I asked the five teacher participants if I could observe them for a 40-to-50-minute teaching session. The teacher participants were chosen based on the focus group students who were in their classes. It is impossible to make an infinite number of observations; as a result, it was decided as to where and when to observe, because it was not possible to be in all the classrooms of the participating teachers. I developed a time sheet specifying the time and the venues where the five teachers were to be observed while facilitating mathematics lessons in their own classrooms. Each lesson was marked as Lesson 1 (Ms. Hanekom), Lesson 2 (Mr. Smith), Lesson 3 (Mr. Tromp), Lesson 4 (Ms. Van Turha) and Lesson 5 (Ms. Adams), see **Appendix C** (example of lesson observation feedback form).

During the lesson observations, there was an awareness, by me (observer), of any action that constituted problem-solving behaviour. Chadwick, Bahr and Albrecht (1984) suggest that observations must be systematic in order to assist researchers to pay particular attention to those categories of action determined by the researcher's specific objectives and questions. Chadwick et al (1984) outline the following challenges of using observations:

- Observers may sometimes not see or hear what goes on or may misinterpret what is observed because only part of the situation was visible or audible to them;
- Selective perception can influence what we are observing. Observation took place with teachers for at least 12 months and during that period; there was an awareness of this possibility and took steps to address it as well as clarifying points after the observation with the teacher;
- Senses do not operate independently from our past experiences. What we observe and the interpretations we attach to what is observed are influenced by what we have previously seen. As an assistant head teacher in charge of raising standards across the school, lesson observations formed part of the

researcher's responsibilities as were the teachers' experiences of being observed; and,

- The process of observation tends to influence the phenomenon that is being observed. The teachers who took part in this research were observed several times before through in school monitoring, for example, SLT and HoD mathematics. Therefore, this presence in their classrooms would have been mitigated to some extend by the existing relationship and expectations.

One of the advantages of using classroom observations is that they offer the researcher an opportunity to gather 'live' data from naturally occurring situations (Cohen et al., 2015). This means that observations enable researchers to study behaviour as it occurs. Another advantage of observations is that they allow the researcher to collect data first-hand, thereby preventing contamination of the factors standing between him or her and the object of research (Nachmias and Nachmias, 1996). In this study, classroom observations were used to support and validate the data collected during the interviews and allowed me to see the lived experiences of the participants within a classroom setting. Furthermore, interpretive research of a high quality can be transferred to other contexts and teachers can benefit from it. For example, in this research study about individual students and teachers I uncovered valuable information, such as how they approach students in answering their questions, their attitude towards challenging behaviour; about classroom life that has inspired teachers and positively affected their practices.

Majac Secondary School's teaching and learning policy states that when a teacher is observed they need to receive feedback on their teaching practice. Therefore, after each classroom observation, the teacher and I reflected on the lesson. During the reflection session I provided the teacher with an opportunity to respond to the following questions:

- What went well in the lesson?
  This question relates to Research Question two
- What did not go as planned in this lesson?
  This question relates to Research Question three
- What are the reasons the lesson went well?
  This question relates to Research Question five
- What are the reasons the lesson did not go well?
  This question relates to Research Question two

Based on the responses to the above questions, field notes on students included how they learned, their involvement, how they responded to their teachers and peers, and the prevalence of those issues that are supposed to dominate or form part of learning such as activity-based learning, contextualised learning, and application of mathematics (Mortimer and Scott, 2003). On the instructional strategies I noted the extent to which the teachers were prepared for the lesson, the subject matter delivery activities, how they responded to the students' needs and their questioning styles. The pertinent issues emanating from the detailed notes written during lesson observations were used in subsequent interviews (especially the informal post lesson talks or conversations) with teachers, students and head of department (HoD). This was to help develop a deeper understanding of the didactical culture of the mathematical department being scrutinised.

Therefore, learning through observation plays an important part in teaching. In order to make the most of opportunities to observe classes taught, the research had to have a clear focus for the observations (to focus on some of the research questions of the study), established suitable procedures to help me describe what I will see, and that I should remain an observer in the lesson and not an evaluator or a participant.

3.9.6 Focus Groups as Research Methodology

To answer the central research question, stated in Chapter One, conducting focus group research I wanted to examine the issue of student achievement from the perspectives of the student, and it helps answer one of the sub-research questions in the study, namely, *what were the key participants' perceptions of their successes and failures in the study?* This approach, congruent with a constructivist research approach, where "people actively construct or make their own knowledge and that reality is determined by the experiences of the learner" (Elliott et al 2000: p. 256), allows for the inclusion of another perspective in this study, that of student achievement. In addition, adding these focus groups to the data collection methods in this study provides also for analysis at a micro level. This level includes the student's family, school, peers, and neighbourhood. The micro level contains bi-directional relationships, for example, a student is able to actively form social relationships with other students in drama, physical education, singing class.

Focus groups are a participatory form of qualitative research and can be viewed as group-based interviews which can reveal a range of opinions and perspectives on a topic (Wibeck, 2011; Harisha and Padmavathy, 2013). In addition, researchers may use focus group discussion to explore a topic, obtain information or narratives for use in the later stages of the research, for example testing narratives (Zander, Stolz, and Hamm, 2013) and developing questionnaires (Kelboro and Stellmacher, 2015). Other studies have used focus group discussion to clarify and extend findings, such as motivations for different resource use regimes (Manwa and Manwa, 2014; Harrison et al., 2015), qualify or challenge data collected through other techniques such as ranking results through interviews (Zander et al., 2013; Harrison et al., 2015) and to provide feedback to research participants (Morgan et al., 1998). Therefore, focus groups possess elements of both participant observation and individual interviews, while also maintaining their uniqueness as a distinctive research method (Liamputtong, 2011). Focus groups draw upon respondents' attitudes, feelings, beliefs, experiences and reactions in a way where other methods are not applicable. A focus group allows the researcher to gather more information in a shorter period of time, generally two hours (Kreuger and Casey, 2015; Stewart and Shamdasani, 2015). The goal is to create a truthful conversation that addresses, in depth, the selected topic.

Krueger and Casey (2015) list various uses of focus groups, many of which fit well with this study's purpose. These are to:

(a) elicit a range of feelings, opinions, and ideas;

(b) understand differences in perspectives;

(c) uncover and provide insight into specific factors that influence opinions; and,

(d) seek ideas that emerge from the group.

According to Cohen et al (2018) the following should be considered when conducting focus group interviews:

- Deciding on the number of focus groups for a single topic. One group is not enough;
- Over-recruiting by as much as twenty percent considering people who may not turn up;
- Keeping the meeting open-ended but to the point;
- Deciding on the size of the group; and,
- Ensuring that participants have something to say and feel comfortable enough to say it.

Taking both views on focus groups from Krueger and Casey (2015) and Cohen et al (2018) into account, where both authors state their approaches, therefore this study adopted a blend of Kruger and Casey (2015) and Cohen et al (2018) approaches so as to meet the needs of the study's objectives and the characteristics of the participants.

It must be acknowledged that focus groups while serving a useful function are not without disadvantages. The use of focus group discussion technique is not recommended when there is a risk of raising participants' expectations that cannot be fulfilled or where "strategic" group biases are anticipated (Harrison et al., 2015). Since focus group discussion depends on participants' dynamics, it should be avoided where participants are uneasy with each other or where social stigmatisation due to the disclosure may arise (Harrison et al., 2015). In such situations, participants may not discuss their feelings and opinions freely or hesitate to participate in the topic of interest to the researcher. Focus group discussion provides depth and insight, but cannot produce useful numerical results, hence must not be used where statistical data are required (Morgan and Krueger, 1998; Bloor et al., 2001).

Careful planning was required for the focus group interview questions. Initially, designing interview questions that adequately reflected what was required by the research questions was vital (Cohen et al., 2018). While it was necessary to formulate semi-structured focus group questions that were focused on answering the research questions, it was important at the same time not to be too specific (Bryman, 2012). The researcher would be able to interpret what is relevant in a specific sense rather than seeking to understand and clarify what the participant saw as being relevant. In this way, he could gain insight on what the participant subjectively perceived as being significant in relation to the focus of the research. This process helped in ensuring that the focus group interviews elicited the views and perspectives of the participants, which was important ethically (Polkinghorne, 2005) for the integrity of the research and important in a substantive sense for the contribution to understanding that the data would make.

As part of Majac Secondary School's in-school monitoring and evaluation procedures, groups of students were regularly interviewed to get their views on different aspects of the school. The familiarity of this type of group discussion, as opposed to one-to-one interviews, which are used in school for investigating poor behaviour, make it more likely that the students gave honest responses in this situation. Therefore, two sets of 50-minute formative focus group interviews were convened with two sets of five participants, see **Appendix D** (Student Consent Form). The semi-structured questions were asked of the participants to which they replied without hesitation. The students were seated around a table, with the supervisor (as an observer) and me (the researcher). This arrangement took advantage of one of the benefits of the group interviews (Morgan and Krueger, 1998) which is their similarity to a normal classroom discussion despite being inevitably artificial. The focus group interviews were semi-structured with guiding questions and prompts, see **Appendix E (**Student Focus Group Interview Questions**)** but with the flexibility to pursue lines of enquiry stimulated by responses. While I was making notes that helped me drive the focus group's activities forward and to keep within the time available for the group; my supervisor (as observer) was tasked with making detailed notes about the actual content of the discussions, validate the information obtained, *and* ensured the trustworthiness and credibility of the data.

The study included two groups of five students in different mathematics class sets. Grades 3-6 were used, but the highest grade that can be achieved is a Grade 6. Sub-grades a, b, c was used, so the highest possible grade in Year 7 was ‘6a’ and the lowest was ‘3c’ (see below Tables 3.5 a and b)

Table 3. 5 (a) and (b) Student Participants' Mathematics Ability Sets

Student Name (Pseudonym)	**Cohort A - Set in mathematics**	**SATs level on entry from KS 2**
Dakota	3	4a
Hayden	4	4c
Logan	5	3a
Ray	1	6c
Sam	2	5a

Table 3.5 (b) Student Participants' Ability Mathematics Sets

Student Name (Pseudonym)	**Cohort B – Set in mathematics**	**SATs level on entry from KS 2**
Alex	3	4b
Brook	4	4b
Gray	5	3b
Julian	2	5a
Roan	1	6c

The student participants were being observed in classroom activities at the beginning of data collection; then one group at a time took part in a focus group interview. The two focus group interviews were carried out to explore information pertaining to their school experiences and their education in mathematics (Sander, Field and Diego, 2001). Participants selected were identified for potential inclusion by the teacher, because the aim for the focus group interview was to bring people together at one time so that they could discuss the questions of interest in a collective manner, which revealed the main issues, aspects or themes that I explored in great depth via individual interviews with their teachers. This overall sampling strategy was selected given the nature of this study, the research questions and three data collection methods. In summary, three kinds of primary data were therefore collated.

3.10 Ethical Considerations

Ethics within educational research involve making choices "on the basis of moral and ethical reasoning" throughout the research process (Basit, 2010: p.56). In any research study, ethical issues relating to protection of the participants are of vital concern (Pring, 2000; Merriam, 2002, 2009; Schram, 2003; Marshall and Rossman, 2015).

Specific ethical procedures were approved by the University Research Ethics Committee, see **Appendix F (**Ethical Approval). All ethical procedures were designed to be accessible to students (see, for example, consent forms and parental permission was sought. Included within the British Educational Research Association guidelines is the statement that researchers must seek to minimise the impact of their research on the normal working and workloads of participants (BERA, 2018). Before the initial semi-structured one-to-one interviews and focus group commenced, the Headteacher and school governors agreed that research with the students and teachers and therefore the participants were asked to review a participant information sheet and signed a consent form required for participation in this study. Both semi-structured one-to-one interviews and focus groups were conducted in a quiet area, the library of Majac Secondary School, away from the rest of the school and were audio recorded in their entirety. At the end of each interview (semi-structured one-to-one and focus group), the audiotape was transcribed verbatim. When transcribing the interviewees' statements verbatim, it is acceptable to leave out fillers in speech patterns, such *as um, ah, like, you know*, unless it greatly changes the context of what was stated (Adams, 2011; Jongbloed, 2011; Evers, 2011).

3.11 Anonymising Data

I took great care to ensure no identification because of your obligation as a researcher (BERA, 2018). Therefore, all participants (teachers and students) were assigned a pseudonym. All data are secured in a safe place. Hard copies of transcripts are kept in a secure locked cabinet and electronic data are password protected and stored on one personal computer.

3.12 Reliability and Validity

Kvale and Brinkman (2009: p. 245) state that "reliability pertains to the consistency and trustworthiness of research findings". They discuss a number of reliability issues, such as (i) interviewer reliability, where the interview technique, such as using leading questions, might influence the responses; (ii) where the categorisation of answers might be biased to support the interviewer's views and (iii) where reliability is undermined when answers are transcribed by different people. Care was taken to avoid leading questions, to be open-minded when categorising answers, checking and rechecking for evidence of themes and presenting alternative opinions from the data (Hughes, 2010). As interviews and observation are common methods for qualitative inquiry, one way of controlling reliability in interviews is to use highly structured interview formats (Silverman, 2015). Structured formats suggest elements of control and consistency; aspects sought after for quantitative research. Restricting the type of interviews used to achieve reliability in this way may not be helpful, however, for the aims of the research. There are other alternatives for achieving reliability including inter-rater reliability. One way of assessing inter-rater reliability is when another researcher uses the same theoretical framework to observe material to establish if they would interpret it in the same way (Cohen et al., 2018), providing credibility and demonstrating levels of precision and evidence of transferability. For Phase One, inter-rater reliability was established according to the recommendations provided by Krippendorf (2004), who notes the need for those involved in qualitative research to be mindful and careful of using reliability measures and issues several recommendations for achieving reliability. One of the recommendations includes the use of additional coders as a way of ensuring greater reliability of data. Krippendorf (2004) also recommends that the agreed coefficient should measure agreements among multiple descriptions of units of analysis. Krippendorff (2004: p.242) further stated: "even a cut-off point of $\alpha = .80$, meaning only 80% of the data are coded or transcribed to a degree better than chance, is a pretty low standard by comparison to standards used in engineering, architecture, and medical research".

In Phase One, the researcher's first supervisor independently undertook coding sample of semi-structured one-to-one teacher interviews and focus group interviews with students. The first supervisor randomly coded items from the interview transcripts. The coding reliability ranged from 92-100% accuracy with an average of 95.8%. Similarly, 12.9 % of the teacher interviews were randomly chosen and coded for five items from the interview transcripts. The coding reliability overall ranged from 87% to 93%. In addition, the semi-structured interviews and focus groups were recorded and transcribed.

Kvale and Brinkman (2009: p.246) define validity as "the truth, the correctness and the strength of a statement" arguing that a valid argument should be well grounded, justifiable, strong, and convincing. Validity can be difficult to ensure in the context of small-scale, opinion-based research. Kirk and Miller (1985) claim that to establish validity great care must be taken to ensure the questions asked of respondents are appropriate. Care was taken to avoid these errors with the qualitative methods, that is, semi-structured teacher interviews, classroom observations and student focus groups. The questions in the interview and focus group schedules were designed following an appraisal of the literature and perspectives from respondents have been mapped to emergent themes in the literature and analytical framework.

For the student focus group interviews, the supervisor's notes represent a high level of reliability and therefore satisfy the recommendations suggested by Krippendorf (2004). The design of the present study incorporated two qualitative phases (Phase One and Phase Two) situated within an intervention study supported by Bronfenbrenner's (1979) ecological systems model.

Furthermore, the analysis of data from both the qualitative phases informed the design of the intervention study. In effect, the design of the intervention itself provides triangulation where the data collected in Phase Two were used to demonstrate its reliability and validity from qualitative research paradigm, therefore adding strength to the research.

3.12.1 Quality Assurance: Validity of the Research Findings

Triangulation refers to the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena (Patton, 1990). Triangulation also has been viewed as a qualitative research strategy to test validity through the convergence of information from different sources. According to Cohen et al (2018), triangulation is appropriate in the following instances:

- when a more holistic view of educational outcome is sought;
- where a complex phenomenon requires elucidation;
- when different methods of teaching are to be evaluated;
- where a controversial aspect of education needs to be evaluated more carefully;
- when an established approach yields a limited and frequently distorted picture; and,
- where a researcher is engaged in a case study.

Triangulation is a method used by qualitative researchers to check and establish validity in their studies by analysing a research question from multiple perspectives. Triangulation is widely used in a number of disciplines as varied as astrophysics (Gribbin, 2008); neuroscience (Robson, 2009); nursing (Thurmond, 2001) and education (Altrichter et al., 1996). Cohen et al (2018: p.254) define triangulation as an "attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint". Similarly, Altrichter et.al., (1996: p.117) regard triangulation to achieve "a more detailed and balanced picture of the situation". In this study, a multiple triangulation method was followed in which qualitative data gathered were used in the form of:

- classroom observations;
- student focus group interviews; and,

- semi-structured one-to-one teacher interviews.

The triangulation approaches that were employed in this study can be categorised into the following types:

3.13 Data Triangulation

Data triangulation involves using different *sources* of information to increase the validity of a study. For example, both Bailenson and Yee (2006), Mark, and Kobsa (2005), discussed below in the context of investigator triangulation, use multiple groups of participants, as do very many other studies. In the case of an afterschool programme, for example, the research process would start by identifying the stakeholder groups such as youth in the programme, their parents, schoolteachers, and school administrators. Data triangulation was used for this study and data sources for the focus groups comprised Year 7 and Year 9 students and teachers. Data interviews were obtained from teachers and students from Majac Secondary School in mathematics. In-depth interviews could be conducted with each of these groups to gain insight into their perspectives on intervention outcomes. During the analysis stage, feedback from the stakeholder groups would be compared to determine areas of agreement as well as areas of divergence. Burns and Grove (1997) assert that responses from such multiple data sources enhance the reliability of the research results. This type of triangulation, where the researchers use different sources, is perhaps the most popular because it is the easiest to implement; data triangulation is particularly well suited for intervention given the different stakeholder groups that have vested interest in these activities.

3.13.1 Methodological Triangulation

Methodological triangulation involves the use of multiple qualitative and/or quantitative methods to study the program (Kimchi, Polika and Stevenson, 1991). For example, results from surveys, focus groups, and interviews could be compared to see if similar results are being found. If the conclusions from each of the methods are the same, then validity is established (Burns and Grove, 2003).

For example, a qualitative approach in the form of classroom observation and focus group interviews were used in order to gain insight into the study, and findings of this approach were used to formulate an instrument for Phase Two of the study. If the findings from all of the methods draw the same or similar conclusions, then validity has been established. While this method is popular, it generally requires more resources. Similarly, it requires more time to analyse the information yielded by the different methods.

3.14 Representativeness of Study

The data in the study represent a distinct type of student access and views from teachers in one institution, Majac Secondary School. It is also important to note that access to the study participants (teachers and students) is unique as these findings are not generalisable, it is hoped, however, that they provide insight into issues that are of wider concern and therefore may be of relevance and useful to other secondary schools who may be interested in considering their own secondary mathematics interventions.

3.15 Coding of Data

Data Analysis of interviews and focus groups: Semi-structured Interviews and focus groups were recorded, transcribed verbatim and data were coded (see below). The following procedure was developed:

1) each interview was transcribed verbatim;

2) each interview was read and re-read several times;

3) lesson observations were noted;

4) an initial coding list was compiled manually;

5) comments were coded manually; and,

6) comments were then clustered into specific themes.

The second stage of the analysis used the Krueger (1994) 'long table' approach.

Table 3. 6 Overview of Thematic Areas and Link to Analytical Framework

Thematic Area	Complexity Framework Features	Level of Analysis	Impact
Theme One: Maintaining levels of student motivation and preparation for the future.	Impact of the wider school workforce and environment; concept of levels nested within levels.	Meso level	At exo, meso and levels
Theme Two: The need for active engagement, less or no use of textbook driven lessons and different learning styles as teachers	Levels nested within levels; system characteristics emerging from interaction, engagement, feedback processes, characteristics of teachers.	Exo level	At exo and meso levels

were instrumental in supporting them.			
Theme Three: Lack of teacher subject knowledge and students own personal characteristics to facilitate their learning.	Self-organisation of teachers, continual professional development, feedback processes, levels nested within levels, structures, and processes.	Exo, meso and micro level	At macro, exo, meso and micro

By gathering data from a range of sources, this study explores the challenges, tensions, and merits of an institutional approach to intervene with secondary students of mathematics from multiple perspectives. Therefore, this overarching qualitative action research methodological approach is congruent with a complexity analytical framework (Haggis, 2008), and allows for a much fuller understanding of why and in what way Majac Secondary School provides interventions to support the students' mathematics and, as a result, provides answers to the research questions in this study.

3.16 Bias of the Study

Since the millennium, educational research has been critiqued internationally with regards to its usefulness, validity and relevance (Hartas, 2010). Oancea (2005) drew upon the vast number of written articles that asked educational researchers from Europe and the US to summarise and group the concerns people had. The most relevant finding is related to the methodologies that educational researchers use. It was felt that many methods employed were not reliable and were inconclusive due to lack of rigour. Concerns were raised over bias in interpreting results. Bias is defined by Goddard and Melville (2001) as a systematic distortion of responses by the researcher, the respondents or by the instrument. To decrease bias in this study, attempts were made to address this issue by means of the following:

- A comprehensive literature review;
- A representative sample; and,
- Inter-rater coding of data (focus groups and semi-structured interviews).

Interpretive methods, such as semi-structured interviewing, case studies, participation-observation, archival research, action research and ethnography, are intended for theory building (Sykes and Treleaven, 2009). Unlike a positivist method, where the researcher starts with a theory and tests theoretical postulates using empirical data, in interpretive methods, the researcher starts with data and tries to derive a theory about the phenomenon of interest from the observed data. Interpretive research is a research paradigm that is based on the assumption that social reality is not singular or objective but is rather shaped by human experiences and social contexts (ontology) and is therefore best studied within its socio-historic context by reconciling the subjective interpretations of its various participants (epistemology). As interpretive researchers view social reality as being embedded within and impossible to abstract from their social settings, they interpret the reality though a sense-making process rather than a hypothesis testing process.

3.17 Issues of Trustworthiness

In qualitative research, trustworthiness features consist of any efforts by individual researchers to address the more traditional quantitative issues of validity (the degree to which something measures what it purports to measure) and reliability (the consistency with which it measures it over time Lincoln and Guba, 1985). In seeking to establish the trustworthiness of a qualitative study, Lincoln and Guba (2000) use the terms credibility, dependability, confirmability, and transferability, arguing that the trustworthiness of qualitative research should be assessed differently from quantitative research. Regardless of the terminology used, qualitative re searchers must continue to seek to control for potential biases that might be present throughout the design, implementation, and analysis of the study.

3.18 Confirmability

The concept of confirmability corresponds to the notion of objectivity in quantitative research. The implication is that the findings are the result of the research, rather than an outcome of the biases and subjectivity. To achieve this, it was necessary to identify and uncover the decision trail for public judgment. Although qualitative researchers realise the futility of attempting to achieve objectivity, they must nevertheless be reflexive and illustrate how their data can be tracked back to its origins. As such, the audit trail (Lincoln and Guba, 2000) used to demonstrate dependability, including ongoing reflection by way of journaling and memo, as well as a record of field notes and transcripts, serves to offer the reader an opportunity to assess the findings of this study.

3.19 Transferability

Although generalisability is not the intended goal of this study, what was addressed was the issue of transferability (Lincoln and Guba, 2000); that is, the ways in which the reader determines whether and to what extent this particular phenomenon in this particular context can transfer to another particular context. Concerning transferability, Patton (1990: p.489) promotes thinking of "context-bound extrapolations" (p.491), which he defines as “speculations on the likely applicability of findings to other situations under similar, but not identical, conditions”. Toward this end, the issue of transferability was addressed by way of thick, rich description of the participants and the context. Depth, richness, and detailed description provide the basis for a qualitative account’s claim to relevance in some broader context (Schram, 2003).

3.20 Chapter Conclusion

This chapter has detailed the methodology used in this study and the rationale which underpins it and the methodological choices that were made. First, this study is situated within a constructivist, interpretivist, epistemological context. The overall research design, in the action research study tradition, and range of methodologies (a qualitative focus) are explained and justified. In addition, data collection methods are outlined. Ethical issues, situating the researcher in the context of this study, are considered.

To address the central research question in this study, *given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?* five semi-structured in-depth teacher interviews and ten student focus groups were conducted. Methodological approach is consistent with a complexity theory analytical framework and an interpretative epistemological stance. The next part of this study outlines Chapter Four: findings, analysis, and discussion of Phase One - the initial data collection from teachers and students (2013-14).

CHAPTER FOUR: PHASE ONE- INITIAL FINDINGS AND DISCUSSION

4.0 Introduction

The purpose of this qualitative study was to explore an intervention strategy in GCSE mathematics at Majac Secondary School. Chapter Four will look at the data analysed, discussed and presented which was collected from the first phase of the longitudinal study and involved semi-structured teacher interviews, classroom observations and focus group interviews with students. The emergent themes are discussed in relation to the research questions in Chapter One.

Table 4.1 shows the research questions and the associated data source. Teacher interviews were face-to-face and took an in-depth form, as the intention was to gain access to teachers' experiences of teaching mathematics. The student focus group interviews were face-to-face and the purpose of conducting these and the classroom observations was to identify the method and strategies teachers used for teaching mathematics in the classroom.

Table 4. 1 Research Questions and Data Source

Research Question	Data Source		
	Observation	Teacher interviews	Student Focus group
1. Why do students underachieve academically when the ability to achieve is present?	X	X	
2. What were the key participants' perceptions of their successes and failures in the study?			X
3. What factors contribute to their psychological and academic needs?	X	X	
4. Why is it important to empower able underachievers?	X	X	X
5. How can strategies and techniques help enhance student performance?	X	X	X

In the next section I will discuss the demographic profile of the participants (teachers and students).

4.1 Demographics of All Participants: Teachers/Students

Demographic information provides an understanding of the research participants, and it enables a researcher to gain knowledge of their perceptions, experiences and attitudes.

4.1.1 Demographic Profile of Teachers

Demographic data from the teacher study participants were collected, and the data are presented in Table 4.2. Among the five teacher participants in the sample, 3 (60%) were female and 2 (40%) were male, 3 (60%) have less than three years of teaching experience and 2 (40%) have four to five years teaching experience and 1 (20%) has a Diploma in Education; 2 (40%) have an education related degree and 2

(40%) have a different degree to education (for example, engineering and law). In Table 4.2 alias (for the teachers) were used in order to protect their anonymity.

Table 4. 2 Profile of Teacher Participants

Teacher Participant (Alias)	**Gender**	**Years of experience**	**Qualifications**
Ms. Hanekom	Female	2	Diploma in education
Mr. Smith	Male	3	Degree in education
Mr. Tromp	Male	5	Degree in engineering
Mrs. Van Turha	Female	5	Degree in law
Ms. Adams	Female	2	Degree in education
Total n= 5	Male = 2 (40%) Female = 3 (60%)	1-3 years= 3 4-6 years =2	Diploma= 1(20%) Education degree=2 (40%) Other degrees = 2 (40%)

The female majority in this study is representative of the gender balance in the school workforce (DfE, 2017) where the percentage of female teachers has increased over time. In 2010, 72.9% of full-time equivalent teachers were female, and this percentage has increased in each year. By 2015, 73.8 % of full-time equivalent teachers were female:

- 64.2 % of full-time teachers being female. This represents a significant change since 1993 when a greater proportion of teachers were male [Department for Education (DfE)], 2017; and,
- it has been hypothesised, by the workforce, that the gender mix of teachers could play a role in the observed gender gap in attainment, but this is difficult to measure and there is no strong evidence to date that this is the case (DfE 2017). In this study the focus was not on gender differences in performance in the students and therefore, not relevant to my study.

Understanding teachers' subject qualifications is important for two reasons: teachers' subject qualifications may be correlated with the quality of teaching and the ability of teachers to teach effectively. According to research published by Gibson et al (2013) both Post Graduate Certificate of Education (PGCE) students and Newly Qualified Teachers (NQTs) are of the view that at least one level of subject knowledge above the level they would be expected to teach is needed in order to deliver teaching effectively. Table 4.2 identified the qualifications of the teacher participants and Ms Hanekom was the only teacher with a diploma in education and she volunteered to be part of the research project interventions; and teacher quality may in turn affect student outcomes (Unanma et al., 2013) which can have long-lasting implications for graduate employability and the wider UK economy. DfE (2019) stated that the increased focus on Schools Direct had contributed to a shortfall in the number of trainee teachers recruited in several subject areas, such as mathematics. Therefore, concerns, that there are inadequate numbers of mathematics teachers, poor rates of recruitment and retention and a high level of retirement are intensified the situation of this study. The shortage of qualified mathematics teachers led to Majac Secondary school recruiting teachers without a degree or a PGCE in mathematics which may have an impact on student attainment.

4.1.2 Demographic Profile of Students

Chapter 3 provided a description of the students participating in this study to explain the sampling/selection process. Pseudonyms are used to protect their anonymity. The demographic profile of the students is presented in Table 4.3 below:

Table 4. 3 Demographic profile of student participants

Pupil Name (Alias)	Ethnicity	Set in mathematics	SATs level on entry from KS2	Pupil Premium	English as an additional language (EAL)	Looked after child. (LAC)
Ray	White British	1	6c	No	No	No
Logan	White British	5	3a	No	No	No
Dakota	Indian	3	4a	Yes	Yes	No
Hayden	White British	4	4c	No	Yes	No
Sam	Irish	2	5a	Yes	No	No
Gray	White British	5	3b	Yes	Yes	No
Alex	White British	3	4b	No	No	No
Julian	White British	2	5a	Yes	No	No
Brook	Scottish	4	4b	No	No	No
Roan	White British	1	6c	No	No	No

The research cohort consisted of 10 students in Year 7. All the students were taking the same mathematics course taught by different teachers.

In the student participant sample, there were seven male and three female participants. Table 4.3 identified that seven of the student participants are of White British, one Irish, one White British (Scottish) and one Indian origin. Most students are of White British origin but an increasing and above average (Ofsted, 2014), proportion came from other backgrounds. There are 240 students in the whole population per year group, which was split into two groups (A and B) with approximately 120 students in each group. English as an additional language (EAL), Pupil Premium (PP), Children (LAC) and Special Educational Needs and Disability (SEND) students were evenly distributed in each group (A or B). As the researcher, I only studied a sample of the student population, as indicated in Table 4.3, to inform the reader(s) about the sample of respondents in the focus group interviews. The belief is that this sample is representative of the larger student population at Majac Secondary School. The next section discusses the Phase One analysis of the semi-structured teacher interviews, classroom observations and student focus group interviews.

4.2 Analytical Approach of Semi-Structured Teacher Interviews

The data analysis followed the process of inductive analysis. According to Fraenkel, Wallen, and Hyun, (2012), inductive analysis is when the researcher begins by exploring open questions. The researcher undertakes this process of inductive analysis by being immersed in the details and specifics of the data to determine significant categories, dimensions, and interrelationships (Fraenkel, et al., 2012). The detailed findings gained from the data were summarised and categorised into general interpretation. The first step in the process of analysing the data involved open coding. During open coding initial categories are formed by studying the information received during the data collection (Creswell, 2009). Figure 4. 1 (a) displays the initial coding stages (with a key which indicates the different coding elements) of the semi-structured one to one teacher interviews. The key concepts: *Motivation to learn* with similar concepts are highlighted.

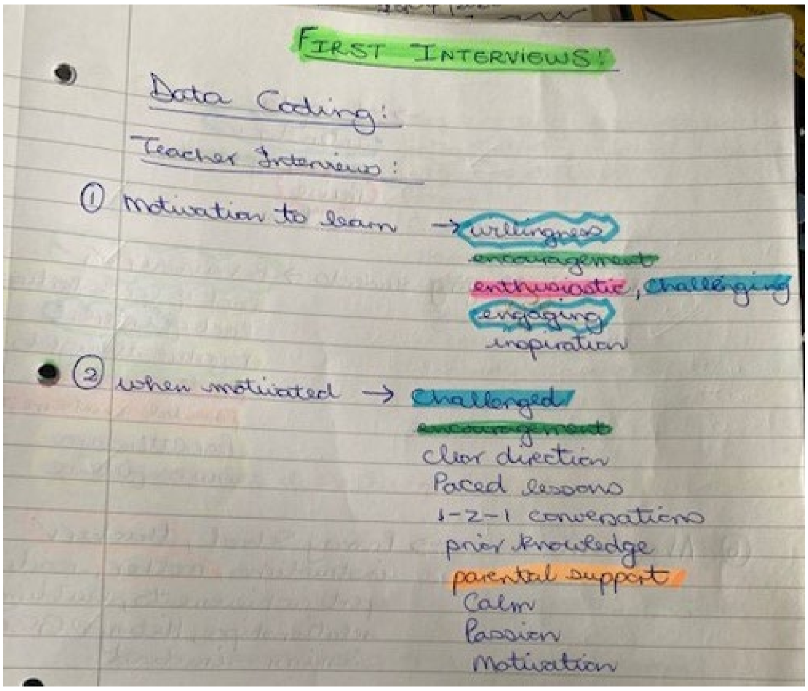


Figure 4. 1 Start of Initial Coding

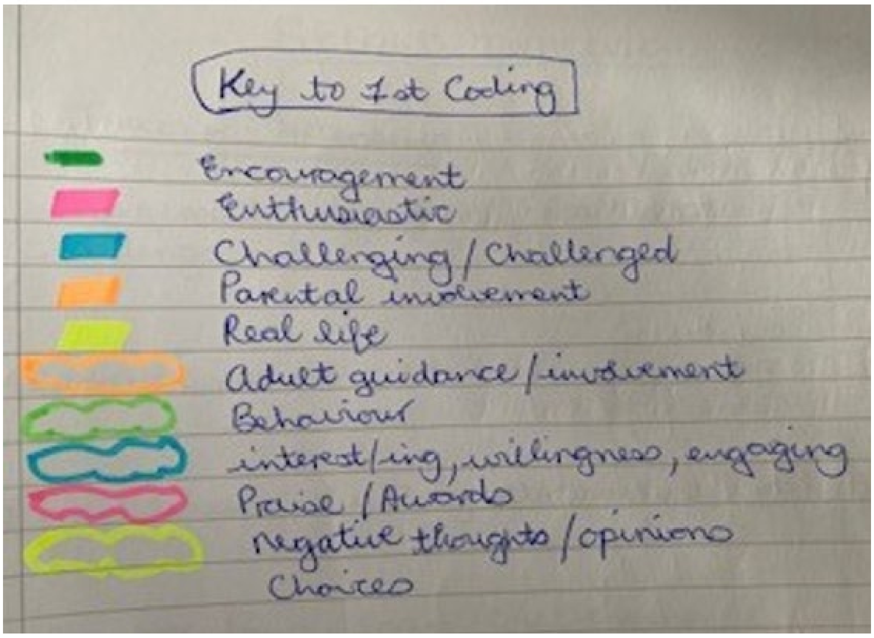


Figure 4. 2 Key to Open Coding

Figure 4.2 displayed how the key to develop Open Coding was used. The data was read through several times and then tentative labels were created for the pieces/blocks of data that summarised what was observed (not based on existing theory; rather based on the meaning that emerged from the data). Examples of participants' words were recorded and established properties of each code.

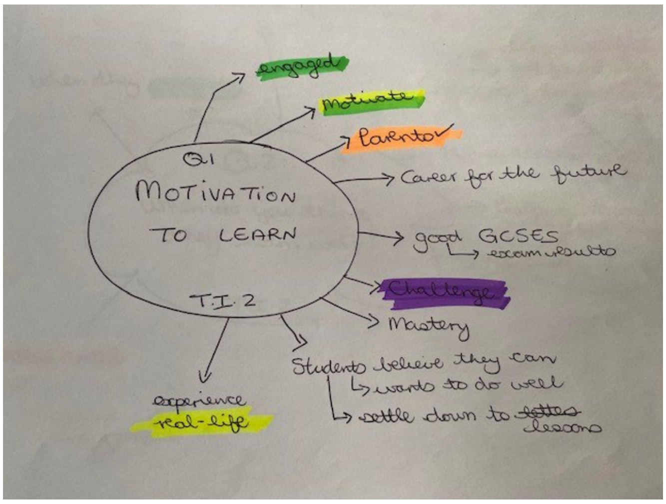


Figure 4. 3 An Example of Open Coding

Figure 4. 3 Shows how the coding relates to the research questions as identified in Table 4.4, below

Table 4. 4 Open Codes for Research Questions

Open Codes for Research Questions	Related coding	Selective coding
	Fun, Pride Greater interaction between teacher and student Learning takes place. Teacher showed. Humour, fun, engaged. Provide guidance. Model good practice Active engaged. Hands on Interesting lessons provided.	Need for Engagement
	Personality of teacher –important Greater interaction between teacher and student Patience for struggling students	Lack of Motivation
	In work /jobs Real life Shopping Paying bills Control of money	Future of Maths

Relationships were identified among the open codes. For example, what were the connections between the codes? **Appendix G** and an extract from Figure 4.3, **Appendix H**, shows how the connections between the open codes developed. As codes were created for new concepts, it was anticipated to come to a point when there would be more than few pages of codes. At that stage, the codes were analysed to find the similarities and group them into categories based on their common properties. The name of the category was different from the codes to express its scope more adequately.

Figure 4. 4 below, a sample set of codes generated from a qualitative analysis for the connection between the Open Codes developed

Open Code	Properties	Examples of Participants' words
Features Of A Good Classroom	Learning takes place Good relationships between teacher and student Personality of teacher –important Active engagement	Most of your classes the teachers are **nice** They're really **nice** and **supportive** A couple of teachers that **help me** You have **favourites** that you think you learn and get the most out of **Get along with your teacher** then it's **better learning** My **teachers** and they're all, **Kind**

Figure 4. 4 Sample Set of Generated Coded

The first level of coding was therefore completed by examining the interview transcripts and selecting key words and phrases that were used (Figure 4.3). Some of the words that occurred multiple times included *engaged*, *achievement*, *challenge*, *enthusiasm*, *teacher and future* (Figure 4.3*)*. To determine how much emphasis was placed on each term several aspects were considered. During interviews, there was an awareness of non-verbal information (such as laughter or gestures) given by the participants as this added meaning to the responses (Ary, Jacobs and Sorensen, 2010). A mind-map was developed for each question in the focus group interview, Figure 4.5 below, explains how the teachers identified ideas and thoughts of when students' *learning* took place.

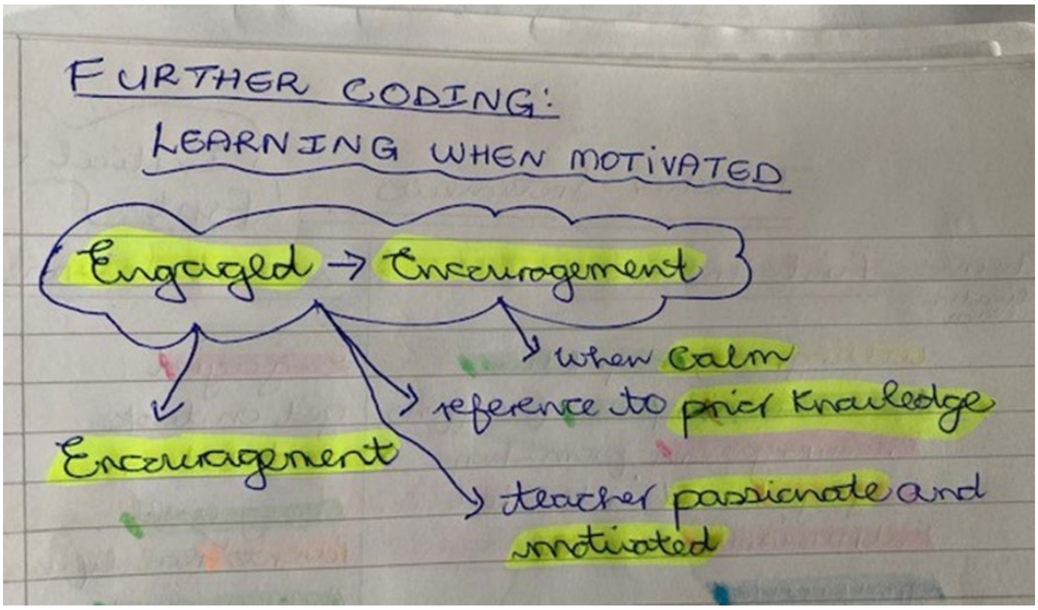


Figure 4. 5 Teachers' Ideas and Thoughts of Students' Learning

As each new transcript was read and coded, the list of codes was increased and amended through a process of constant comparison. The whole set of data was then re-read against these codes, noting where in the data they occurred. This allowed a review of which codes recurred most frequently, which were interesting but rare or unique, and began to provide insight into the themes emerging from the data. The next step was to carry out a process of selective coding, determining the "adequacy and conceptual strength" (Charmaz, 2014, p.140) of the initial codes and identifying those that occurred most frequently, were most interesting or surprising or presented as an anomaly. The selective codes arising from the interview-based data were:

- Need for engagement
- Lack of motivation
- Future of mathematics

This level of coding has been described as axial coding (Ary, et.al. 2010). Basit (2010) expresses that axial coding involves linking categories and codes and interconnecting them with main categories. The diagram displayed in Figure 4.1 (e) – *Teachers' ideas and thoughts of students' learning* shows how several open codes were connected. The diagram depicts how the components of mathematics learning, engaged and encouragement are created using words, such as, *passionate* and *calm.*

Also depicted are reasons for the participants' subject knowledge in class and why this is important in students' future careers. Creswell (2014) explained that similar codes need to be grouped together into themes. He added that, these themes are established after considering the codes that arise frequently and have evidence to support them. Therefore, after the codes in this research study had been established and then categorised, they were developed further to create specific themes. These themes incorporated the major categories of the previous levels of coding. The themes developed over time as more data were received and analysed. Although the majority of the data that contributed toward the creation of the themes came from teacher semi-structured interviews and the students' focus group interviews, the analysis of other data gained (lesson observations) also added to the creation of the themes.

4.3 Analytical Approach to Lesson Observations

Observations were originally seen as a significant section of the data collection process. The way the observations were utilised developed over time through the process of emergent design and from a researcher perspective this approach met the needs of an action research project. Emergent design allows flexibility so that adjustments can be made to the research project (Drew, Hardman and Hosp, 2008). Data collection methods are one component of a research study that may be changed throughout the research process so that the information that is gained is meaningful (Creswell, 2014).

The field notes that were taken while observing mathematics lessons provided useful information that was then able to be used during the semi-structured teacher interviews. Student and teacher interview participants were asked questions that related both directly and indirectly to the field notes that were taken during class lessons. This was important because observations on their own, do not directly represent students' or teachers' perceptions (Linn and Miller, 2005).

Coding was also completed on the field notes to gain information to reinforce students' and teachers' perceptions about mathematics and their effects on students' and their learning. The coding of the observations occurred concurrently with the coding of the semi-structured teacher interviews. In the first instance, a concept mapping approach was used to determine overarching or 'global' characteristics of teachers' practices that identified three aspects for further investigation: teacher actions; teacher discussions; and teacher expression (Stake, 2000). Detailed notes of each teachers' practices recorded how and where teachers stood, physical movement of the teachers around the room, how and when they spoke to students, and how they responded to and interacted with students verbally and non-verbally.

A second level approach to coding considered the teachers instructional practices for engagement in mathematics. This process began by listing the instructional practices of Ms Hanekom's lessons and then distinguishing between the mathematics instruction and pedagogic components. This process was guided by Martin's (2007) Motivation and Engagement Wheel (hereafter referred to as the Wheel) where he extended the idea of motivation and engagement as a multidimensional construct (Martin, et al., 2011) for considering multiple motivation theories. The Wheel has operationalised an interrelated combination of constructs from six key theories of achievement motivation: attribution theory (Weiner, 1985), expectancy-value theory (Wigfield and Eccles, 2002), goal theory (Elliot and McGregor 2001), self-determination theory (Ryan and Deci 2000), self-efficacy theory (Bandura, 1997), and self-worth motivation theory (Covington, 1992). As displayed through Figure 4.6, the Wheel was grounded in multiple theories of achievement motivation and includes both positive and negative factors.

The eleven factors of the Wheel align with Fredricks, Blumenfeld, and Paris' (2004) three components of engagement: behavioural, cognitive, and emotional. The factors of the Wheel represent a diverse theory-driven framework for research aimed at explaining motivation and engagement. In this study certain features are shared between engagement and motivation because of the underlying sources of energy that are reflected in engagement characteristics. For example, persistence (being an adaptive motivation) may be observed by time spent on tasks by students and asking questions by teachers, which are also characteristics of behavioural engagement. Often, engagement is connected to the learning environment (the school) because it reflects an individual's interaction within contexts (Fredricks, Blumenfeld, and Paris, 2004) as the underlying motivational processes may be harder to determine.

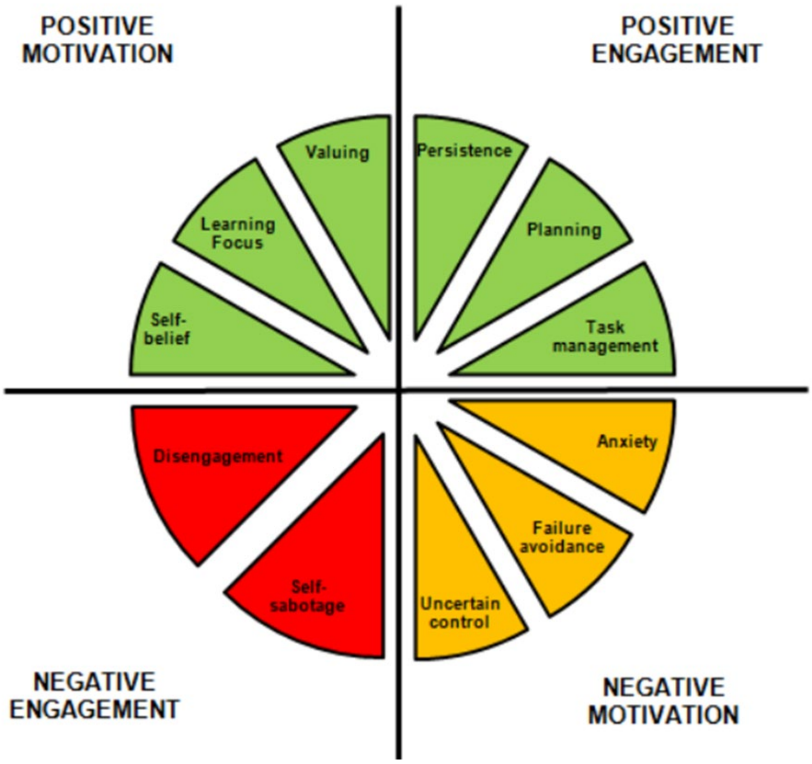


Figure 4. 6 Motivation and Engagement Wheel (Martin, 2007)
(*Reproduced with permission from the Lifelong Achievement Group*)

The lesson observations of all teacher participants continued to be analysed and it recorded their practices in the same way, adding new practices to the list until saturation was reached. At the conclusion of this process, the list of practices was consolidated and categorised as representing certain characteristics. The labels applied to describe each of the categories were drawn from relevant literature, again satisfying origination, verification and nomination requirements (Constas, 1992). The eight categories identified were:

Promote engagement;
Involve students;
Active engagement;
Interactive lesson or textbook lessons;
Promote good subject knowledge;
Keep student motivation all the way through the lesson;
Promote collaboration; and
Promote monitoring and feedback.

As an example, comments by teachers that were coded 'promote good subject knowledge' incorporated several teacher practices including:

- Makes content aims clear;
- Check prior knowledge of students;
- Reinforce learning objectives as mini plenaries sessions;
- Gives clear instruction/structure for tasks; rephrases if required;
- Use pedagogy to illustrate challenging mathematical content; and
- Elaborates meaning or gives examples showing typical use.

During the coding process, instructional episodes were noted that stood out as being shared amongst the teachers or events that signified unique practices by particular teachers and demonstrated differentiated practices in their classrooms (Gerring, 2007). These episodes were reported in the results by way of exemplars to provide illustrations of practices found in classrooms with teachers who were identified as engaging. In the next sections the findings from the semi-structured teacher interviews, classroom observations and focus group interviews with students will be discussed.

4.3 Analytical Approach to Student Focus Group Interviews

Despite the abundance of published material on conducting focus group interviews, scant specific information exists on how to analyse focus group data in qualitative research. This is surprising, bearing in mind (a) the relatively long history of focus group research (Morgan and Krueger, 1998); (b) the complexity of analysing focus group data compared to analysing data from an individual interview and (c) the array of qualitative analysis techniques available to qualitative researchers (Leech and Onwuegbuzie, 2008).

To date, no framework has been provided that delineates the types of qualitative analysis techniques that focus group researcher/s have at their disposal. In this section, I identify qualitative data analysis techniques that are best suited for analysing focus group data. The frameworks of Leech and Onwuegbuzie (2008) suggest several qualitative analysis techniques that can be used to analyse focus group data. Specifically, the analytical techniques that lend themselves to focus group data are constant comparison analysis, classical content analysis, keywords-in-context, and discussions analysis (Leech and Onwuegbuzie, 2008). The constant comparison analysis was best suited to this study as it analyses many types of data, including focus group data. In the constant comparison analysis, three major stages characterise the analysis (Strauss and Corbin, 1998). During the first stage (Open Coding), the data are placed into small units. The researcher attaches a descriptor, or code, to each of the units. During the second stage, (Categorising Coding); codes are grouped into categories and in the third, (Selective Coding), the researcher then develops one or more themes that express the content of each of the groups (Saldana, 2013). Therefore, the constant comparison analysis, was the best method especially as there were multiple focus groups within this study and it also follow what I did for the semi-structured teacher interviews, therefore comparing the processes and making them the same made sense. Because focus group data were analysed one focus group at a time, analysis of multiple focus groups effectively served as a proxy for theoretical sampling, which is when additional sampling occurs to assess the meaningfulness of the themes and to refine themes (Charmaz, 2000). Thus, I could use the multiple groups to assess if the themes that emerged from one group also emerged from other groups and similar with the semi-structured teacher interviews. Doing so would assist me reaching data saturation and/or theoretical saturation.

Therefore, the focus group transcripts were read through frequently to become familiar with the overall picture of data (deductive analysis). That is, the approach was used to discern an overall and fundamental meaning of experiences (Hall, 2006). Line by line in-search of the transcript was undertaken to scan central themes (for example, *teachers were not able to maintain high levels of student motivation in lessons*) which included repeated ideas or statements that said something (Leech and Onwuegbuzie, 2008). This process was accompanied by making notes about each student's words using different colours for different themes (for example red = the meaning of the characteristics of the teacher [*nice, helped me, supportive*], (Figure 4.2

highlight these words) blue = the meaning of who supported the student [*one other teacher, a few teachers, supply teachers*]).

The focus group data analysis effectively serves as a proxy for theoretical sampling, which is when additional sampling occurs to assess the meaningfulness of the themes and to refine themes (Charmasz, 2000). Therefore, based on the data that have been analysed, further data analysis was unnecessary. As claimed by Fusch and Ness (2015: p. 1408) "failure to reach saturation has an impact on the quality of the research conducted". Given (2016: p.135) stated, that saturation is the point at which "additional data do not lead to any new emergent themes".

On completion of the first reading of the focus group data, it allowed me to immerse in the data and thus the 'life world' of participants (Gillis and Jackson, 2002) as it provided a systematic collection and analysis of the data for the purpose of taking action and making change by generating practical knowledge.

Once the main themes were highlighted, sub-themes were created for each theme (for example, sub-theme one: all themes about the meaning of maintaining high levels of motivation and how mathematics relates to the future). Initially, as many sub-themes as possible were generated and materials of relevance were linked accordingly. Then the number of sub-themes were reduced (collapsing stage) joining the ones that have similar contents (Leech and Onwuegbuzie, 2008). Once the final version of sub-themes was finalised, each of them was examined within the context of each question reported in the interview schedule. As qualitative analysis is an ongoing and dynamic process, the interview transcript was checked again to ensure the credibility of analysis.

The extent to which certain themes are based on actual data were re-checked and reinforced by examples. Given the nature of qualitative data and the complexity of its quantification, an interrater reliability coefficient was computed. My first supervisor and I, read through one set of the focus group interviews (*emergent*), discussed the given themes and sub-themes to examine the level of agreement. The discussion was informed by examples of significance reported by student participants. As a result, some changes were made to the themes and sub-themes labels as well as the related content. For example, the theme of a good class teacher came strongly through when coding the data, but in discussions with his supervisor, they agreed that the theme can be consumed with one of the other themes.

Whilst measures were undertaken to enhance the credibility of data, it is unwise to claim that bias was entirely eradicated in this work. Arguably, the only way of analysing qualitative materials without manipulation would be to offer the transcript whole and unanalysed, so the readers themselves could judge them (Miles and Huberman, 2009). The above thematic procedure was applied to focus group interviews discussions (n=2) and focus group participants (n=5). In the next section the findings of the semi -structured teacher interviews, classroom observations and student focus groups interviews will be discussed.

4.4 Semi -Structured Teacher Interviews, Classroom Observations and Student Focus Group Interviews- Findings

The teachers in this research were mathematics teachers. The focus of their lessons was students' *learning of mathematics* and its improvement. The students in this research study were interviewed to establish their understanding of their teachers' *teaching of mathematics* in the classrooms. Both teachers and students were interviewed to determine their views of factors that facilitate achievement in mathematics and strategies that support students' learning in mathematics. In this respect, an interview guide (Silverman, 2013) was used. **Appendix I** contains the questions asked and a summary of the interview guide.

The data provided for the teacher semi structured interviews, lesson observations and focus group with students will be related in the form of qualitative self-reported data. The quotes listed in the discussions form just a small part of the larger conversations and observations.

In addition to providing verbatim statements made by the participants, whenever possible, information was utilised concerning the number or proportion of members who appeared to be part of the consensus from which the theme emerged. Furthermore, the number or proportion of members who appeared to represent a dissenting view as well as how many participants did not appear to express any view at all were noted. In addition, the student participants, because merely agreeing to a majority view either verbally (for example, by using statements such as "I agree" or "Yes"; by making an utterance such as "Uh-um") or nonverbally (for example, nodding one's head or smiling) might reflect some level of agreement, it was documented how many focus group members provide substantive statements or examples that generate or support the consensus view. Table 4.5, below, identifies my first supervisor's and my own notes which supported information about the level of consensus and dissension to facilitate this information-gathering process

Table 4. 5 Matrix for Assessing Level of Consensus in Focus Group Interviews

Focus Group Question	Member 1	Member 2	Member 3	Member 4	Member 5
1	SA	SA	SA	SA	SA
2	SA	SA	SA	SA	SA
3	SA	SA	SD	SA	SA
4	SA	SA	SD	SD	NR
5	SA	SA	SD	SA	NR
6	SA	SA	SD	SA	SA
7	SA	SA	SA	SA	SA
8	SA	SA	SA	SA	SA

Key for the table:

A = Indicated agreement (verbal or nonverbal)
D = Indicated dissent (verbal or nonverbal)
SA = Provided significant statement or example suggesting agreement
SD = Provided significant statement or example suggesting dissent
NR = Did not indicate agreement or dissent (nonresponse)

Several research projects by Onwuegbuzie, Collins, and their colleagues (DaRos-Voseles, Collins, and Onwuegbuzie, 2005; DaRos-Voseles, et al., 2008) have provided much evidence of the important role that group dynamics play in determining group outcomes. Thus, it is reasonable to expect the composition of the focus group to influence the quality of responses given by one or more of the participants. Focus groups that are heterogeneous with respect to demographic characteristics, educational background, knowledge, experiences, and the like, are more probable to affect adversely a participant's willingness, confidence, or comfort to express their viewpoints (Stewart and Shamdasani, 1990; Sim, 1998). Thus, it was important that my supervisor and myself made notes and monitored the group dynamics continuously throughout each focus group session.

When students were asked '*how mathematics should be taught at secondary school,* they stated*:*

RO: … fun games. …learn in … games instead of reading out of textbooks. …you can go back to the textbook to look at …time's table and division …

JU: …it's really pressurised … a test in a week and then in a month … tests …don't really, further our learning and …less … constant revision for the test …just free learning...

JU: … more just learning …for a test and … another test …

BR: … videos and stuff on how to do it … also … doing … examples on the board and …, copying it down yourself and then having a go…., the teacher comes over and helps you … you just really don't get the question and sometimes the teacher can't even help you with that.

GR: …using lots of different learning styles … rather than …teacher stand at the front and explain … go to a certain page in the textbook and then copy things down… it's nice … sometimes a video or getting the children up at the front doing it or going down to the library or using the computers is much more effective.

AL: … the more passionate the teacher is, the more you learn … the more … the teacher is really into this topic and then you start to get into it.

When the participants talked about '*how mathematics should be taught'* it became evident that their actual experiences showed what is happening in their lessons and this relationship linked well with their understanding of the concept before the question was asked. The students were aware of the classroom situation and therefore knew what to answer without hesitations. Therefore, the overall finding on '*how mathematics should be taught'* at Majac Secondary School involved different interactive resources, for example, '*go back to the textbook*' '*pressure of tests'* and '*copying from the board'*.

The wording of the questions and subsequent comments made by other participants in the group influenced the context within which the comments were made. Some of the participants were never directly asked to talk about '*how mathematics should be taught*' issue, although when the conversation moved to talking about what improvements they would suggest all felt the need to listen to other participants and think about what they could say. They also talked about previous occasions when similar things happened to them or in their current classes. The finding of active engagement developed through student statements, for example, '*showing videos and stuff ...but… doing ... examples on the board and… copying it down yourself and then having a go*. Three students stated:

JU: … it's really pressurised … oh, you've got a test in a week and then in a month …
RA: … we had revisions like big tests and stuff, because it was quite stressful, so it would be kind of sitting doing textbook work…
HA: … everything that's actually in the test, and it's hard … to move on to something new when you don't really understand the topic…

The synthesis of the students' ideas on this topic shows that they felt pressured in mathematics lessons with the testing 'culture' and that fewer of these assessments would support them learning better.

Figure 4.7, below, indicates that the students received support from a range of people (teachers, instructors) in their learning and developing journey

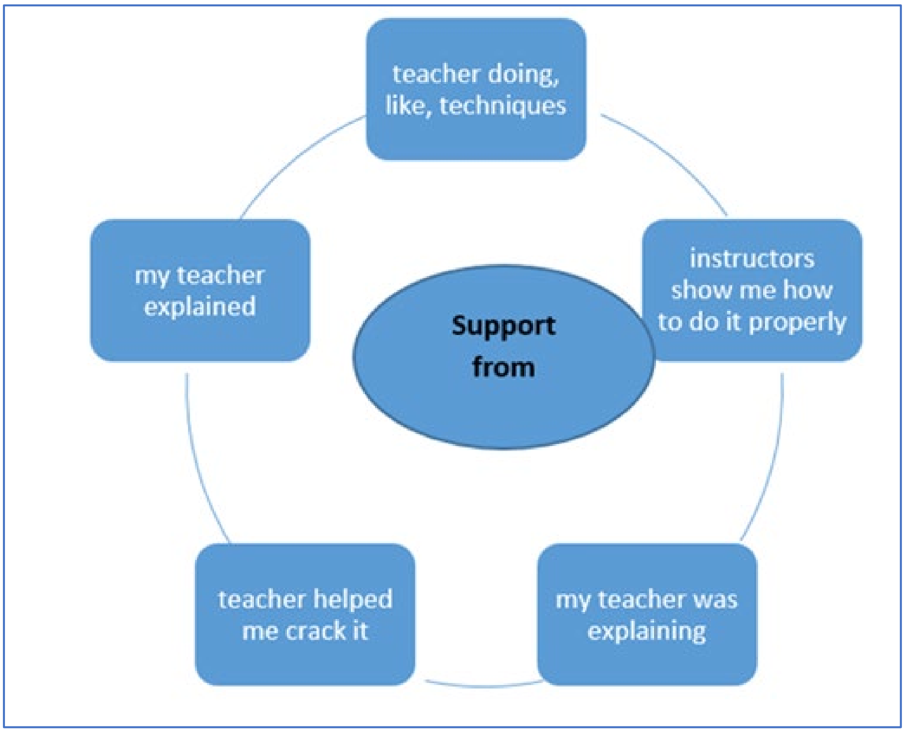


Figure 4. 7 Students Identified Who They Received Support From

Three students stated:

HA: … Well, there's, like, most of them they're really *nice* and *supportive*

LO: … Most of my teachers are *helpful* and *nice*…

AL: … I had difficulty learning Maths and then at the end she started *doing, ..., techniques* and then I got it much easier…

Figure 4.6, below, identified when students had a good learning experience in their classrooms. They indicated that a *good learning experience* can be engaged, interactive, fun, risk taking, with patience, and modelling.

Figure 4. 8 Students Good Learning Experience

Three students stated:

GR: … they used a video to teach us how, rather than just having to try and work it out using the textbook…

BR: … showing, … videos and stuff on how to do it is quite good…
… a bit of humour when she's teaching…

RO: … very firm and … strict and that helps people … learn more.

Figures 4.7 and 4.8 illustrated what was found when the data was analysed. The analysis of focus group data can take a wide variety of forms. These may range from very rapid, highly subjective impressionistic analyses to very sophisticated computer-assisted analyses. Rather, the approach that was most consistent to this study's purpose and could represent the richness of the data to create intervention strategies to support students who are struggling with mathematics, and the information needed gave rise to it.

The next section discusses how the findings in regard to learning and teaching mathematics emerged as three themes: *the need for motivation, lack of engagement* and *teacher subject knowledge*; through semi-structure teacher interviews, lesson observations and focus group interviews with students.

4.5 Emerging Themes

This section contains three main themes which emerged from analysis of the Phase One data:

Theme One: Lack of ***motivation*** affect students' engagement with learning and their preparation for the future.

Theme Two: The need for ***engagement***, less or no use of textbook driven lessons and different learning styles.

Theme Three: Lack of ***teachers' subject knowledge*** and students' own personal characteristics to facilitate their learning.

These themes emerged from a thematic analysis of the data and will be followed by a summary of the implications of the data at the end of the chapter.

Using the principles of Framework analysis, three main themes and several sub-themes were identified. These are presented in Table 4.6 below.

Table 4. 6 Conceptual Framework Outlining the Main Themes and Sub-Themes

THEMES	**SUB-THEMES**
1. **Lack of motivation** - The overwhelming majority *(8 of 10 [80%])* of the student participants indicated that their teachers were not able to maintain high levels of student motivation in lessons and all participants indicated that the use of mathematics in the classroom does not help and prepare them for the future. They find the mathematics challenging and unrelated to their future.	1.1 Pressured through lots of testing. 1.2 Effectiveness in fostering students' learning 1.3 Mathematics applies to real life
2. Need for **active engagement** - All participants expressed the need for active engagement in lessons and less or no textbook driven lessons. More than half of the participants asked for activities for different learning styles.	2.1 Different learning styles 2.2 Active shared engagement 2.3 Use of Technology 2.4 Teacher Involvement
3. Lack of **teachers' subject knowledge** - The majority of participants cited lack of teacher subject knowledge as a barrier standing in the way of their progress and that they relied on their own personal characteristics to facilitate their learning progress.	3.1 Teacher cannot help with certain questions 3.2 Difficulty in learning mathematics

Table 4.6 provided a summary of the themes and sub-themes emerging from the findings related to the semi structured teacher interviews, lesson observations and focus group interviews. A discussion of these themes and sub-themes generated from the data will now be presented using this framework, which will include the identification of any relevant inter relationships between these

4.5.1 Theme One: Lack for Motivation

A motivated teacher is crucial to a successful classroom (Stroet, Opdenakker, and Minnaert, 2013). They will look at teaching through a different lens, and, in doing so, motivate their students in their learning too. Motivation helps to energise, direct and sustain positive behaviour over a long period of time. The overwhelming majority (n=8) of the student participants indicated that their teachers were not able to maintain high levels of student motivation in lessons and all (n=10) participants indicated that the use of mathematics in the classroom does not help and prepare them for the future. Evidence from teacher semi-structured interviews, lesson observations and focus group with student participants are presented below:

> Ms Hanekom was asked '*what motivates her students and when do they learn well?*' she stated:
>
> EMH: …motivation… from an enthusiastic teacher…working together is good motivation…
> EMH: …when there is challenge …clear direction …lessons …paced … to reflect and give feedback ...
>
> According to Ms Hanekom, the most difficult student in mathematics can be motivated when:
>
> EMH: …you can tap into a pupil's behaviour and attitude. …you … work closely with them …
> …role model that they're lacking… providing... of real life and the amount of time students spend in the company of teachers, they can't but be influenced by the teacher.
> …you're in contact with these children … the impact is huge…
>
> On the question of '*what motivates those students and when do they learn well?*' Mr Smith provided the following response:

RMS: … the willingness to complete the work and get to the finish line …and then receiving praise…
…when they're challenged …allow … time to struggle…in their own mind. …when they're pushed, or ... challenged to learn something …

According to Mr Smith, the most difficult student in mathematics can be motivated when:

RMS… a small little victory …getting someone interested…, and … put a … scaffold in so that they can build up their confidence …

Ms Van Turha was asked '*what motivates those students and when do they learn well?*' she stated:

DMvT: … relationships with teachers, encouragement from home.
When they are engaged and interested…

According to Mrs Van Turha, the most difficult student in mathematics can be motivated when:

DMvT: … try really …hard. I think persistence... students …now come and ask… for help because I've just kept plugging away

To motivate her students to succeed in mathematics at Majac Secondary School and the future, Ms Van Turha stated that she:

DMvT: … getting them to think … the process they're going to go through … applying for university …what the university's going to be looking at, rounded people not just academically bright people.

According to Mr Tromp was asked '*What motivates those students and when do they learn well?*' he stated:

NMT: … future outcomes in life, so that's a big personal motivation… the teacher can inspire some motivation... big influence would be their parents…
…when they are calm...earlier on in the day. …so, they're focused, and they're motivated... the teacher is passionate and motivated.

When I asked Mr Tromp how the most difficult student in mathematics could be motivated, he replied:

> NMT: …through …time...

To motivate his students to succeed in mathematics and the future, he stated:

> NMT… given an infinite amount of time... But sometimes it takes a heck of a long time!
> … it's so much to do with progress these days and data that... it's all about getting to the next level or exceeding that…I try and keep it as well organised as possible and students hopefully work as hard as they can…

Mr Tromp's reaction to the question on the background that will impact students' motivations and achievement was notable and when asked how he interests his students with mathematics in the classroom, he replied:

> NMT: …my questioning skills are good … class discussion is good-ish... and … the rich questions …take time to plan carefully that are important …off topic conversations…lessons related to sport and statistics in sport...

When Ms Adams was asked 'what motivates those students and when do they learn well?' she stated:

> SMA… one-to-one conversations …motivate them … their friends to help motivate them or saying …they've done well in previous lessons, using that to encourage them. …some students' parents' help …call home… motivate them.

When Ms Adams talked about her KS3 history lesson, she disclosed how motivated she was and when I asked her what she does to motivate her students and their future career paths, she responded:

> SMA: …go back to previous learning … you try and explain it to them again… … I encourage them …and… conversations. …what are the three goals that we can set for you for next week…help support them?

Answering the question on motivation in performance due to students' background and home circumstances, three teachers stated:

> SMA: …motivate students, you know, those students who come from difficult backgrounds and they turn to their teachers for advice and use their teachers for motivation. …
>
> JMM: … I think that the teacher has an effect as well, but I think the encouragement …is massively important.
>
> EMH: … motivation comes from an enthusiastic teacher. Group work, challenging tasks, problem solving, working together is good motivation for them. What was the second part of the question?

Motivation increases students' learning (Theobald, 2006). Students' learning can increase because of their own innate desires to perform or accomplish a task; however, students' learning may be affected by external factors such as rewards or incentives (Bain, 2004; Theobald, 2006). Students' learning is not entirely dependent on their own motivation. Teachers' play a vital role in increasing students' learning through motivational support (Thoonen, et al., 2011; Schuitema, Peetsma, and Oort, 2016). The following quotes from five of the student participants evidence the teacher comments:

> **JU**: …gives me guidance to how I should do it.
>
> **HA** … told me what to improve on, so I improved
>
> **SA**…make..., most of the lessons interactive, which was always nice to have, sort of, a few interactive lessons.
>
> **DA**…she just used to help you a lot and make lessons fun
>
> **LO**… she was nice … helped you… always there and … answered your question.

Jacobs (2020) SEMISM, adapted from Bronfenbrenner (1979), identifies that human development takes place through interactions between an active and evolving human organism and the persons and objects in the surrounding environment. The theme of motivation confirms the literature that enhancing students' motivation in the mathematics classroom is an important issue for teachers and researchers, due to its relation to students' behaviour and achievement; and support the value of motivation in students' mathematics learning.

Sub-Theme 1.1: Pressurised Through Lots of Testing

Student participants mentioned that they feel pressured with the amount of assessment in mathematics. As stated by five students:

> **JU:** …it's…pressurised …you've got a test in a week … all these tests … don't…further our learning....
>
> **LO**… you're stuck in your seat and you're stuck in a textbook…
>
> **GR**…teacher stand at the front and explain how to do it and then go to a certain page in the textbook and then copy things down …
>
> **RO**…we had revisions …big tests… it was quite stressful, so it would be kind of sitting doing textbook work
>
> **BR**… end of topic test…... we hadn't gone over … everything that's actually in the test, and it's hard to… move on to something new when you don't really understand the topic before.

The qualitative analysis of focus group data, teacher interviews and lesson observations indicated that the key implication for teachers are to create safe learning environments and to help students develop positive motivational attitudes, since those who are less anxious are more likely to succeed in mathematics. Jacobs (2020) SEMISM indicates that in the meso level all participants encouraged active engagement in mathematics which could lead to enhanced student levels of motivation (*micro level*).

Sub-Theme 1.2: Effectiveness in Fostering Students' Learning

There is little dispute that teachers are impactful agents in students' educational pursuits. During the lesson observations teachers (n=3) used strategies, such as, '*think pair share'; kahoot* to enhance student learning through their teaching. It was also quite clear that some teachers (n=2) were more effective than others, through their *questioning* and *activities* they offered to the students, therefore, models of teaching and learning recognise that teacher, student, and context variables influence student educational experiences and academic achievement. It would seem; therefore, students' different experiences of teaching and learning affects the student's achievement as stated by four students:

> **GR**: …good fun…everyone in the classroom involved …do this dance …to construct graphs.
>
> **LO:** …when you do something which is boring you don't really remember it as much if you enjoy something and learn. When you enjoy it then it tends to stick in your head more.
>
> **HA**… they're really nice and supportive…. they help a few people that are…really struggling ...
>
> **JU…** like, n^2 equations and I didn't really get it, but then my teacher finally explained it to me, and I finally got it

Three teachers stated:

> <u>RMS</u>: …taking part and particularly when you... arguably you're learning most when you're describing something
> … I will sometimes have off topic conversations but in terms of plugging into them in a more professional way that is related to the learning, I'm not very good. Sometimes... I have had a couple of lessons related to sport and statistics in sport, but, no, not very well
>
> <u>EMH</u>: … a good learning, high quality learning, experience but also an enjoyable experience where they're able to show aspects of their personality as well as their success in their work…
>
> <u>SMA</u>: … I try and always go back to previous learning, so I always say maybe you've done this in primary school

Jacobs (2020) SEMISM identifies that in the exo and meso levels teacher characteristics (such as, commitment, caring, tolerance) supports the students learning and developing in achieving their best possible results in mathematics.

Sub-Theme 1.3 Mathematics in Real-Life

The student participants mentioned that teachers should prepare them for the future through *real-life* application. Jacobs (2020) SEMISM identified that in the exo level the linkages and processes between settings (home and school) need to support the real-life world of the students. Three students stated:

> **SA**: …paying tax bills, water bills … keep control of your money …
>
> **BR**: …diabetic …maths comes up…got to add, like, how much insulin I'm having, how many carbohydrates I'm counting…
>
> **HA**: …. if you just know maths…fluently then it's much easier in life. …little things that make it easier if you know maths.

Students in this study understood that they needed mathematics in the real world to support them. During the lesson observations the students commented that they enjoy lessons relating to their real-world experiences, such as, converting money abroad, ratio and proportion (squash and water). The statements, below, from the teacher and students, are important as jobs in the future are increasingly central to economic competitiveness and growth and will provide many of the jobs of tomorrow for young people.

Ms Adams stated:

> <u>SMA</u>: …I …give examples of … real life… you might use this when you're doing a business… Or …statistics …probability …if you want to sell something? …

Two students agreed with the teacher's approach and responded:

JU: … it's really important… it has…really good basic maths skills.
AL: Many jobs you need to learn … to do maths…numbers do come up and you've got to know how to do that…

It is suggested that students' motivation may be thought of as patterns of behaviour and affect. Three sub-themes have been described and these sub-themes would probably describe most students and address the concerns of many teachers. It should also be pointed out that these sub-themes are in addition to, and do not take account of, problems that may arise because of personality or behaviour disorders. If students do not find the work meaningful and tend to make external attributions, then work avoidance may develop. To this point, however, little attention has been paid to meaning in studies of academic motivation. Yet, I can make a couple of claims about meaning. If students do not understand what it is they are supposed to do, then they may not be able to find meaning in their work. If the topic does not make sense, they may not be able to discern the relevance of the topic. Likewise, if students do not feel capable of understanding the topic, they may not find the work meaningful. Consequently, there are a number of implications for teachers. First, teachers need to communicate to students the objectives of the lesson; what it is the students should learn. Doing so may enhance the students' self-efficacy for the task at hand by helping students feel confident in their work (Schunk, 1982; Ames, 1993). Teachers may also consider how to promote autonomy and self-direction in the classroom because how teachers construct classroom environments may impact on students' perceptions of competence and autonomy in the classroom (Boggianno and Katz, 1991; Ames, 1993; Ryan and Deci, 2000). Ultimately, though, the critical factor in the learning process may be how the teacher and students interact. Teachers who are perceived as being nurturing, supportive and helpful will be developing in students a sense of confidence and self-determination which will be translated into the learning-oriented behaviours of the intrinsically motivated student (Seifert and O'Keefe, 2001).

4.5.2 Theme Two: Active Engagement

Active learning engages students in activities beyond reading, listening, or watching to deepen their learning and connection with the material. Students engaged in active learning often are talking with each other in small groups or large discussions. developing skills rather than memorising information. All participants (teachers and students) expressed the need for active engagement in lessons and less or no textbook driven lessons. More than half of the participants (n=7) asked for activities for different learning styles.

Theme Two emerged in relation to discussions about teachers and students' beliefs; their judgments of confidence to perform academic tasks or succeed in academic activities. Jacobs (2020) SEMISM discerns that students live in the micro level and this is where development occurs. Teachers will have more positive impact on student development when they operate at the microsystem level in direct relationships. Therefore, in the meso level, student development would be enhanced if the roles, activities, and relationships in which the student engages in, within the setting (school), "encourage the growth of mutual trust, positive orientation…" (Bronfenbrenner, 1979: p. 214).

Sub-Theme 2.1: Different Learning Styles

Learning styles are a way of perceiving, conceptualizing, and problem solving; a preferred way of interacting with and responding to the environment (Francis, 2000).

They are cognitive, affective, and psychological indicators of the manners by which students perceive, interact with, and respond to their learning environment (Matthews, 1996). Students who learn with their preferred learning styles are more likely to gain more knowledge and skills when taught and counselled through their natural or primary style rather than through a style that is secondary or undeveloped, particularly when they are presented with new materials or engage in new experiences (Matthews, 1996). This research was interested in whether students and teachers believed that many of the learning problems in school were because students were not being taught in '*their learning style'*; students and teachers could not really suggest what being taught in '*their learning style*' would look like.

When discussing their own approaches to learning and teaching, the teacher participants, spoke of using motivation as an approach to teaching therefore, three teachers stated:

> NMT**: …** you're learning most when you're describing something because you've having to understand it, you're developing that understanding as you're explaining it…
>
> EMH**: …** motivation comes from an enthusiastic teacher. Group work, challenging tasks, problem-solving, working together is good motivation for them
>
> SMA.**:** …. you can…motivate students… they…use their teachers for motivation.

Four student participants reported that teachers are instrumental in their learning and stated:

> **HA:** … I was really bad …he helped me ...to get better.
>
> **BR***:* ... when they…show you how to do it …you … copy that and then it's easier to…do it.

> **LO**: …I had a good teacher because she was nice and, … she always helped you … always there and…answered your question.
>
> **DA**: …she just used to help you a lot and make lessons fun.

Jacobs (2020) SEMISM recognises that inhibited factors such as ability, experience, knowledge and skills development *(micro level)* in the teaching and learning environment restricts conveyance and increase of knowledge and skills, leading to undesired outcomes. Therefore, teaching and learning could be teacher-centric, using direct teaching methods (*exo level*) which is focused on the student and concentrated on the *person* or *context* characteristics and/or student's' strengths.

Textbooks reflected the way of organising students in any year group and a particular textbook scheme might have different textbooks aimed at different sets of students. Teacher participants all (n=5) said that they used textbooks regularly, because students need to practice exercises selected by the teachers following teacher explanation of a particular concept or procedure. Three students stated:

> **GR …**using lots of different learning styles is good …. then go to a certain page in the textbook …
>
> **RO…** learn from… games instead of reading out of textbooks. Sometimes you can go back to the textbook to look at…times table and division...
>
> **SA:** … they could be really interactive because …, textbooks, … are a little bit boring…

During lesson observations I observed the textbook used in the lesson was simply as a source of exercise to which Rezat, (2013: p.743). stated:

> …the textbook should arouse students' interest in learning mathematics, help students to study mathematics actively, develop students' potential in creativity through the process of learning basic knowledge, improve students'

> mathematical thinking when trying to understand the essence of mathematics knowledge, and raise students' awareness to apply mathematics knowledge in everyday lives.

Learning mathematics with a textbook comprises activities such as reading explanatory texts and acquiring new content, looking through worked examples, solving tasks. It is the teacher who orchestrates the students' use of textbook materials during the lesson. Therefore, the same textbook as an instructional tool could be used differently in different mathematics classrooms. Teachers may or may not use the textbook in the lessons; they may simply use it as a source of exercise, or they may utilize the full potential of the materials presented in the textbook.

Sub-Theme 2.2: Active Shared Engagement

Students discussed that interactive whiteboards are supporting their learning as they learn concepts faster or retained a higher percentage of material when the information was presented graphically and rapidly the teachers in the study can use it without significantly disrupting teacher-centred classroom practices. Consequently, three students stated:

> **SA…**they could be …interactive … because textbooks are …. boring …
> **RA**: …teacher... used to let us work on the board and stuff …
> **…** go on the board and on the computers
> **LO…** I'd like some interactive games on the whiteboard…

Jacobs (2020) SEMISM indicates that in the *exo level* new ideas about how technology can improve learning and encourages implementation of the new ideas in the classroom could be built upon through pedagogical and subject content knowledge.

Four teacher participants stated that:

EMH: …I provide … keys to open …doors…the qualities they will need… I often have a conversation …about what they want to become when they're older. …using aspects of maths … they are always striving to achieve a goal

… the Shape aspect strand of maths... encouraging them...praising them…on how that can improve

RMS… they need to access what they don't know and then get the required skills, so… they can progress from their mistakes …

DMvT: …the teacher has an effect …the encouragement …from home is massively important

… I have some idea what they're interested in. …I listen to what …they …say...

SMA: … building that relationship … show that you care …, I'm here and I'm going to make sure they get the best out of what we can offer them.

During the lesson observations, most teachers, (n=5) used IWBs to engage students with the learning and teaching of mathematics and the student participants (n=8) reported that they would enjoy mathematics when classes were interactive and engaged. Therefore, three students stated:

SA: …make … lessons interactive…

…they could be really interactive because …. textbooks…, are …boring and… put you off

HA: …They have interactive lessons, but …still be hard so people can be challenged ...

LO: … make lessons more interactive because we usually always do textbook work and … textbook it gets … really boring, … I'd like … interactive lesson

Furthermore, three student participants stated, below, that active learning through collaborative groups support their development and learning in mathematics lessons:

SA: …when we do group work … with your friends …fun time learning.

LO: … make lessons more …a textbook it gets…really boring…

DA: … lessons …outside of the class …measuring stuff …to make it funnier…

Jacobs (2020) SEMISM provides a guiding framework useful in constructing innovative learning materials (*exo level*) and teaching strategies *(meso level)* that meet student learning needs, motivate participation, and enhance student engagement. In addition, with the understanding that active learning leads to more engaged students, teachers know that students learn mathematics by doing mathematics, as students supported above.

Sub-Theme 2.3 Use of Technology

The student participants (n=10) confirmed that they would like to use more interactive resources to engage with their learning. Three student participants stated that:

AL: … she showed us …videos, so you learn it more
RA: … Not only textbooks…. go on the board and on the computers
BR: … showing …videos and stuff on how to do ….

The student participants also liked to have interactive lessons and stated that they would learn better through incorporating technology and active engagement in mathematics. Without having experienced this form of teaching in a mathematics classroom, it is very easy for teachers to teach the way they have been taught in the form of paper-and-pencil tasks, which do not promote the use of engagement between peers and between students and teachers. Jacobs (2020) SEMISM highlights in the *exo level* that it is very difficult for teachers to move out of their comfort zones and teach in new ways when they do not have sufficient practice with teaching mathematics using various media, such as technology.

Sub-Theme 2.4: Teacher Involvement

Student participants said that they would like their teachers to be more involved in their learning, as four students stated:

> **SA: …**the teachers maybe help …more… they say I can't really explain this to you
>
> **LO: …**you're stuck in a textbook it gets… really boring…
>
> **RA**: Helped you and always listened to you
>
> **HA**: **…** they help a few people that are… really struggling…they never …help the rest of the people.

Jacobs (2020) SEMISM indicates that in the *exo level* teacher routines, supported by parental involvement in schooling in turn promote effective attitudes and behaviour in the classroom, including higher engagement and improved performance by students.

When teacher participants were asked: '*When do students learn well?'* Three teachers responded:

> EMH**:** …they learn well when there is challenge …clear direction …lessons are paced well …they're able to reflect and give feedback...
>
> NMT: …when they are calm…... so they're focused, and they're motivated... when the teacher is passionate and motivated.
> …when they're challenged …when you allow students time to struggle with something... when they're pushed, or when they're challenged to learn something
>
> SMA: …when the lesson is engaging …if you show enthusiasm the students want to engage in the lesson.

From the responses above it is evident that the teacher's role from a socio-constructivist perspective is that of a facilitator to students learning, guiding and supporting students' construction of viable mathematical ideas. The teacher participants indicated that they both understood and sought to include principles of posing tasks that bring about appropriate conceptual reorganisations in students' thinking.

Interacting with elements of their relationship with mathematics and depending on their interpretation of the context of the moment, the research participants (teachers and students) engaged in mathematics in unique ways, which in turn affected their experiences and success in learning and teaching mathematics. This section has described the teachers and students' engagement in the subject of mathematics as a whole. The sub-themes stated the students' habits of engagement and identified strategies of disengagement.

4.5.3 Theme Three: Teacher Subject Knowledge

Theme Three emerged from the discussion relating to teachers who are not able to maintain high levels of student motivation in lessons. Most of the student participants (n=9) held the view that all the teachers at Majac Secondary School were qualified to teach mathematics up to and including, GCSE level. From their comments, it was evident that the teachers' comments in lessons demonstrated their lack of subject knowledge and engagement with the subject. For example, three students stated:

JU: … the teacher **…** doesn't really… give us an idea**.**

AL: …learn how to do maths because numbers do come up and you've got to know how to do that...

HA: …she just, … oh, you're good at this. She never, …told me, …, what to improve on…

The finding indicates that there is, clearly, a difference between 'doing' and 'understanding' mathematics. Jacobs (2020) SEMISM identifies that in the *micro level*, the student participants identified the importance of teacher skills, knowledge, capacities, and confidence, which influence identity development within the school setting.

According to Mr Tromp, the students pick up boredom rapidly and this affected their performance levels and then they see mathematics as '*useless and unimportant*':

NMT: …the importance of maths as a problem-solving skill, an ability that you need to practice …developing … systematic method of problem-solving.

When teachers are not trained in their subject, they lack experience and do not have the skills to support students (Thompson, 1996; Moore et al., 1997; Morgan and Bourke, 2005). Three student participants stated:

BR*:* ...Sometimes you …don't get the question …sometimes the teacher can't even help you with that.

DA: …a couple of teachers that help me, … when I'm stuck, but some of them just… tell me to skip it for later or something.

SA: … can be a bit focusing … they're not struggling …they, sort of, put you aside … you cannot do it yourself, even when you're struggling on the topic, they cannot help you and put you aside to work with your mates.

Thus, the question could be asked, what mathematical knowledge is required for teachers to think about the implications and integration of students' mathematical activity for the development of mathematical repertoire and ideas? Since the response to this question would vary for every topic being taught, an obvious solution might be that non-specialist teachers need more personal experience of the mathematical canon, rather than Continual Professional Development (CPD) about teaching methods.

Sub-Theme 3.1: Teacher cannot help with certain questions

What teachers do in classrooms is very much dependent on what they know and believe about mathematics and their subject knowledge is seen important for student achievement and four students stated:

> **BR**…you …don't get the question and …the teacher can't even help you with that.
>
> **HA**: … a few people… really struggling, but they (teachers) never really help the rest of the people…
>
> **LO**: … sometimes …you could be stuck on the same question … you'd still be stuck on that question for ages.
>
> **GR:** … sometimes when we're learning …bisecting triangles or polygons … I can't really see the point of it. I do it, but I can't really see … how I'm going to use it in later life… we ask the teacher he doesn't really … give us an idea.

Successful teachers are those that have good content knowledge and pedagogical knowledge (as recognised by the students above) and can provide the means to realise the good intention. Jacobs (2020) SEMISM acknowledges that the sense of self, self-control, social capital, and activities within professional learning communities at the school *micro level* could be identified as having potential influence on a teacher's ability to teach. The nested structure from Bronfenbrenner (1979), identified that the micro level does not sit in isolation. The interactions, linkages and processes between micro level that teachers have outside the school environment, including families, friends, and networks at the *meso level* layer further add to complexity of how a teacher operates at the school micro level with the student.

Most student participants (n=7) said that they need to understand the mathematics to support their journey to the future. Three students stated:

> **SA**: … paying tax bills, water bills... to be able to keep control of your money …
>
> **HA**: … You can figure out … what's the cheapest option …fluently then it's much easier in life.
>
> **BR**: … when I'm older I want to be a vet and then … up … doses of medication … maths actually comes up in life, day-to-day …

While student participants knew the importance of mathematics for their future careers, they still believe that teachers need to support them in this journey. 'Unknowingly', to the students, the problem with mathematics is that it is taught in ways that is disconnected from them. Three teacher participants stated:

> <u>EMH</u>: … providing them with enough keys to open enough doors, providing them with all of the qualities they will need, so I often have a conversation …
>
> <u>JMM:</u> I think the first thing is getting them to think about what their goals are, because some of them don't really think about it.

Almost all participants (teachers and students) said that the teacher's role is crucial within and outside the classroom. Three teachers stated:

> <u>SMA</u>**:** I encourage them …and … have a conversation…. I'll ask them what they want me to do to help support them. It's maybe not academic.
>
> …as a teacher, show that you care and … to make sure they get the best out of what we can offer them.

EMH: … support their exam and gaining the qualification which they need to continue in their lives and to open as many doors... talk about links to real life and showing that the course content has an impact on their day to day

SMA: … it's about problem solving and puzzle solving and developing their analytical skills, and …connecting it to money …I tend to do examples using money … see how that relates to them …connection with real life

Furthermore, two student participants stated:

JU: …I …could not work out and find the area of a circle …my teacher helped me. … then I could suddenly do it.

RO… I didn't understand how to divide … my teacher was explaining it to me, I understood it.

Teacher knowledge, including SMK and PCK, is the basis for teachers' instructional practices in their classroom. *Encouragement, support* and *care* from the teacher participants would involve teachers in the 'lives and communities' of the students in this study. Jacobs (2020) SEMISM relates the framework to the *macro level*, where the social background and school environment impacts on the students' learning.

What emerged from the data were that the focus was on individual student's mathematical thinking and on what mathematics students do know and what their specific competencies were. These excerpts leverage teachers' dilemmas of practice with individual students to foster the development of caring teacher–student relationships that explicitly attend to issues, such as race, culture, and students' specific learning needs.

Sub-Theme 3.2: Difficulty in Learning Mathematics

The findings from the students show that there is a disconnect between teachers' subject knowledge and their teaching practices. The experience of working with students who do not do well in mathematics raise the concern that students are required to spend so much time in mathematics lessons engaged in tasks, which seek to give them competence in mathematical procedures. The Jacobs (2020) SEMISM identifies that when students are active participants in their learning, a student-centred knowledge construction develop as optimal learning occurs through interactions that are bi-directional and reciprocal (*micro level)*. Therefore, three students stated:

> **SA**: … when we do group work … it's nice if teacher would let you … more fun time learning… interact with your friends
>
> **LO**: … I had difficulty learning maths … she started doing… techniques and then I got it much easier…
>
> **DA:** …put on … a game, so then we can all like join in, and like play. … she'd like make up... Like get up a poem…

Furthermore, during lesson observations teachers engaged students with different activities (for example, pair work; individual learning) and the different learning strategies supported the teacher comments below:

> <u>RMS:</u> … you're learning most when you're describing something because you've having to understand it, you're developing … understanding when you're explaining it…
>
> <u>EMH</u>: … having an enjoyable experience, ... a good learning, high quality learning, experience but also an enjoyable experience where they're able to show … their success in their work

Most students (n=8) commented that mathematics is a difficult subject and that they need to know the content to pass tests and exams. For the student participants to understand the questions and teaching of mathematics, from the teacher participants, the *explanations* and *instructions* needs to be clear and precise. As a student's achievement does not just rely on enough practice of various written exercises. In Jacobs (2020) SEMISM, the *meso level* influences provide some of the clearest examples of the potential of how teacher–student relations may intersect with other social contexts (home) in ways that are relevant to students' personalised learning. Two students stated:

> **SA**: …the teachers maybe help a bit more …they say I can't really explain this to you. It's…, annoying when they can't really do that…

> **GR**… teacher stand at the front and explain…. *go to a certain page in the textbook* and then *copy things down*.

Classroom instruction is a complex enterprise and one of the important aspects of classroom teaching that has been considered for investigation by researchers is the beliefs of students' mathematics learning and mathematics teaching (Wong et al., 2002; Thompson, 2004; Beswick, 2007). Jacobs (2020) SEMISM identifies that teachers' pedagogical and content knowledge in the exo level supports student learning and enhance academic achievement. Three students responded:

> **AL**: …I had *difficulty learning maths* and then at the end she started *doing, ... techniques* and then I got it much easier...
>
> **BR: …** she puts …a bit of *humour* when she's teaching …makes you laugh and … makes *you want to do the work* instead of just sitting there and not paying attention.
>
> **RO:** … she's *very firm* and she is *very strict* and *that helps* people *concentrate* more … learn more.

The students stated that their teachers' beliefs about mathematics teaching and learning would support their academic progress in the classroom, their trust in the teacher, guidance to independence and their teacher understanding of their needs as students.

The data analysed here provides evidence as to the importance to teachers of mathematics in developing subject knowledge for teaching as well as the value of strategies in supporting student learning across a range of learning outcomes of value to teachers. The data also provides further evidence from the student participants in the provision of mathematics learning and how they learn topics of mathematics.

Teachers' conceptual understanding and knowledge is critically important at any level. It follows that when prospective teachers demonstrate limited or confused understanding of the subject knowledge relevant to the lesson, unless rectified, their future students will struggle to make sense of the relevant mathematical concepts. Teachers who are unclear in their own minds about particular mathematical ideas may struggle to teach those ideas and may resort to examples that prevent, rather than help, student development. Teachers' limited knowledge may lead them to misunderstand their students' solutions and may lead them to give feedback that is inappropriate or unhelpful. In short, teachers' fragile subject knowledge often puts boundaries around the ways in which they might develop students' understandings. On the other hand, teachers with sound knowledge make good sense of mathematical ideas. They develop the flexibility for spotting opportunities that they can use for moving students' understandings forward. When teachers use their knowledge to enhance student learning, they are engaging in effective practice. Not only are they advancing students' understandings, but they are also, ultimately, adding value to the wider community of individuals.

Appendix J displays the research studies Themes, and Sub-Themes and shows how they are positioned with the Jacobs (2020) SEMISM. The next section concludes the chapter.

4.6 Chapter Conclusion

Chapter Four comprised the first part of the research, examining factors that facilitate achievement in mathematics. The data was gathered by means of semi-structured interviews with teachers, lesson observations / journal entry notes and focus group interviews with students.

Although both teachers and students from Majac Secondary School discussed different factors that lead to good achievement, there were specific factors that were common to both students and teachers. This study indicates that the relative perceptions of most of the students' concern:

- teachers maintaining high levels of motivation in the classroom;
- the importance of high-quality teaching and learning in the mathematics classroom;
- active engagement in the classroom; and,
- teachers' lack of subject knowledge to support all students.

From the data analysis, three main themes, several sub-themes and categories emerged. In Theme One, the teachers' role of maintaining high levels of *motivation* and the focus of mathematics in the future was discussed. Theme Two reflected the nature and scope of *active engagement* versus textbook lessons, and how different learning styles were instrumental in supporting mathematics in the classroom. Theme Three indicated that most student participants cited lack of *teacher subject knowledge* as a barrier standing in the way of their progress and that they relied on their own personal characteristics to facilitate their learning progress.

The responses of the teacher and student participants to questions asked during the semi structured interviews, lesson observations and focus group interviews were analysed. Analysis of the data lead to three distinctive themes which supported the design of interventions through components that was needed for the *learning* (students) and *teaching* (teachers) of mathematics. Chapter Five, which follows, presents the pre-intervention lesson discussions and the six intervention lessons for Phase One of the study.

CHAPTER FIVE: PHASE ONE - FIRST INTERVENTION

5.0 Introduction

In this section, I discuss the key action research intervention cycles that took place during this research phase. Following the outcomes of the pre-intervention, subsequent cycles were planned, undertaken, analysed and reviewed before the planning of the next cycle took place. In other words, the outcome of one action research intervention cycle affected the development of the next. For each action research intervention cycle, I show here the objectives for the lesson, the lesson activities and the rationale behind the design of the activity. A full summary of the findings of each action research intervention cycle (McNiff, 2010) can be found in section 5.8.

5.1 Pre-Intervention Sessions

Before the action research cycle of intervention sessions, I invited the students for the pre-intervention lessons. The robustness of an intervention's effects depends on the level of students' pre-intervention academic skill (Smith et al., 2013). When schools intervene after a classroom lesson, the student has already struggled and may have negative feelings towards re-visiting work they have already found challenging (Polak, 2017). Pre-teaching is more effective than re-teaching as it can transform the way a student sees themselves and it is important for motivation and engagement (Minkel, 2015). The academic benefit of the pre-intervention sessions seems to run parallel with the findings of Trundley (2017) and Polak (2017) who both found that, following pre-teaching interventions, tests indicated that students' attainment had improved. All pre-learning activities were aimed at helping students to develop levels of curiosity and interest before they learn new material. Through the pre-learning Ms

Hanekom (who volunteered, in the mathematics department meeting, to be part of the action research intervention cycles) and I, introduced mathematical vocabulary because many words have meanings that are different than those used in everyday language, with some words even containing symbols that are not used in the common English alphabet. We also introduced study techniques, such as retrieval practice and mind mapping that support the way the student sees themselves in being more effective in attempting mathematical questions (Minkel, 2015). Furthermore, the pre-intervention sessions would support the students to feel more positive about the intervention prior to the intervention lessons thereby boosting their self-esteem (Earle and Rickard, 2017; Polak, 2017; Trundley, 2017). For example, each activity started with a 15-minute game /activity that the students could choose on arrival and the game/ activity would involve mathematical computation (such as, snakes and ladders, monopoly).

The six pre-intervention sessions which address the conceptual and procedural bases for emerging competence with arithmetic, occurred once per week, 50 min per session for six weeks in a quiet location in the library (which was away from other students). The activities were organised in a folder with materials and guides that provided each lesson's structure, content, and language of explanation. To ensure the natural flow of interactions and responsiveness to student difficulties, Ms Hanekom and I reviewed but did not read from or memorise lesson guides. A lesson plan serves as a guide that a teacher uses every day to determine what the students will learn, how the lesson will be taught as well as how learning will be evaluated. Thus, lesson plans enable teachers to function more effectively in the classroom by giving a detailed outline that they adhere to during each class. Sessions were organised in six areas, see Table 5.1 below.

Table 5. 1 Intervention Sessions

Lesson	**Mathematics Area**
One	Basic Number
Two	Probability
Three	Handling data
Four	Algebra
Five	Geometry
Six	Review of previous lessons

Ms Hanekom and I were responsible for the planning, preparing and delivery of the sessions. During the six pre-intervention sessions we started with different, engaging hands-on activities, for example, the students engaged in activities for 15 minutes. A major challenge for teacher education in the 21st century is to provide society with qualified teachers to teach and prepare the next generation of citizens (Polak, 2017; Trundley, 2017). As Majac Secondary School also lacked experienced qualified teachers I led the input to the lesson, and Ms Hanekom observed the way I demonstrated concepts to the students. The observation allowed her to bridge the gap between practice and theory to enhance her teaching quality as well as the importance of practice-based professional development to maintain her to work as a teacher in a long-term perspective.

Ms Hanekom and I ran each pre-intervention session which benefited the students because a) less time is required to 'hand over' the intervention to another member of staff, b) the student has already struggled and may have negative feelings towards re-visiting work they have already found challenging (Polak, 2017), c) it enabled us to adapt the upcoming lesson based on students' responses during the pre-teaching session, and d) through conversations with students they stated that they value having the quality time with the teachers who are not their normal class teacher (Trundley et al, 2016; Watt and Therrien, 2016; Trundley et al, 2017) as their normal teachers have full classes (at least 25-30 students) and they do not receive the individual attention.

I looked at the marks achieved for the different topic test data (Appendix K), and the areas that students found easy and challenging are shown in Table 5.1 below. Appendix L shows examples of two- and - three-mark questions the students needed to answer which required working to be shown. Those questions that contained a lot of text or involved multi-step problems were not answered well and often were not attempted. When I spoke to some of the students after the sessions, they said that they did not attempt a question if it looked difficult as it required a multi-step process in its solution. During a discussion, while the students were engaged in the activities, I spoke to one of the students (Dakota), and he correctly explained the steps involved in solving a multi-step problem, verbally, even though they did not attempt it. This discussion made me realised that some students knew how to verbalise their answers (Askew et al., 1993) but that they needed practice in showing their workings as required by the examination board. The topics of strength and weakness are displayed in Table 5.2

Table 5. 2 Strengths and Weaknesses Topics of Students

Strengths	Weaknesses
Addition,	Number - percentages
Subtraction	Algebra (all parts)
Multiplication of positive integers	Negative numbers
Calculating simple probabilities as fractions	Interpreting graphs
Interpreting simple bar charts and pictograms	Long division
	Percentages
	Geometry (all parts)
	Negative numbers
	Interpreting graphs

Before the action research cycle intervention lessons, after the pre-intervention sessions, Ms Hanekom and I discussed that this particular group of students lacked confidence in their mathematical ability and preferred to remain within their comfort zone, focussing on routine questions that were all very similar. During the pre-intervention sessions, we observed that soon as they came across something that looked slightly different, they felt as though they could not do it, despite discussion with us afterwards revealing that they could do it. I also observed that they were poor at reading the information given to them in questions and that they would use avoidance techniques to not attempt to work on questions they felt looked challenging. The only way I saw them accessing support when ‘stuck’ was by asking us for help with the hope that we would do it for them. During the pre-intervention sessions with students, I also found that they did not see mathematics as a subject that develops skills they will require for their future. I aimed to address these barriers to learning through the action research cycle intervention lessons.

During the pre-intervention sessions, I also spoke to the students about their learning in their primary school. They revealed that their previous education in mathematics followed the same routine. Each session began with the teacher introducing the topics followed by a number of examples. Following this, they would work from a textbook or worksheet attempting many similar questions, which progressively were getting more difficult. Each question was similar to that of the example. Although the textbooks often had problem solving questions in each exercise, the students told me that they often missed them out 'because they looked difficult'. I often find that textbooks provide very little in the way of motivation or context. Students find it very difficult to learn a topic with no motivation, partly just because it 'bores them' and they are 'disinterested' in the presentation of the context in the textbook. Therefore, it was important for me that students should know more about the background and motivation of what they are learning.

Observations during the pre-intervention sessions further indicated that the students had become encultured into practices of rote learning, procedural competency and the idea of there either being a correct or incorrect answer. In order to address their lack of resilience I needed to carefully consider how I would change this culture of learning. Lee (2006) and Sfard (2007), indicate that students must articulate their mathematical ideas in order to effectively learn mathematics. It seems that placing students in the position of having to communicate what they are learning is at the core of increasing both the students' resilience and their thinking and learning. Sfard (2007) is clear that learning and communicating are intricately intertwined. The current mathematical culture in the school was resistant to student articulation with a heavy emphasis on teacher exposition and little opportunity for students to express their emergent understanding or misunderstandings and this approach did work for the student participants.

In the next section I will discuss the six key action research cycles intervention lessons that took place during the research phase which supported the students' development with the areas of weakness identified in the pre -intervention sessions. The six-action research intervention lessons will each have a: a) Title; b) Mathematical Topic; c) Focus and d) Protocols. Topics were chosen because the mathematics department's plan was to follow the instructions of the textbook of mathematics that the school had adopted. The subject of the topic was a unit of mathematics from the school textbook. The content was new to the students which was prudent in order to prevent students' previous knowledge from becoming a variable factor which could affect the outcomes of this action research part of the study.

5.2 Intervention One: Targeted Individual Lessons

Topic: Number

Title: Percentages

Focus: Learning of mathematical techniques and motivation in mathematics, link to Chapter Two, section 2.4.7

Protocols:

The 10 students:

- used worksheets with clear instructions;
- engaged actively to complete the worksheets by themselves;

Teachers:

- I read out the instructions to the students;
- Ms Hanekom observed the teaching, engaged in discussions with students and answered their questions.

Post lesson reflection: Student engagement: The students' motivation levels were very low, and they needed encouragement to engage in secondary mathematics. In this case, I found that what was missing was real-life application, which I planned to address in the next action research cycle intervention lesson.

Dominant theme: Motivation

Recommendations for action (post lesson): Introduce real-life application

We had set up part of the space as a clothing shop using items from home and the school. Following the sharing of the lesson objective and a discussion about what they were being asked to achieve, the students started the lesson. The students were asked to use the worksheets provided to them with guidance and instructions. These instructions were read out to the group before the task began and I reminded the students about what they could do if they 'got stuck'. Following these instructions, students were asked to complete the questions in any order. An example question is given below in Figure 5.1

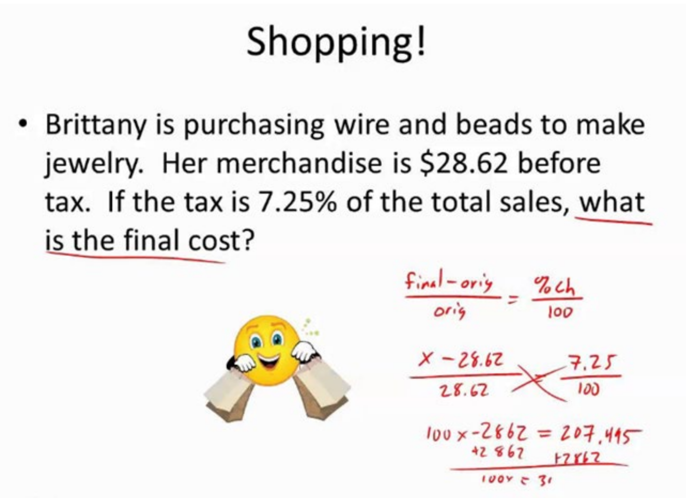


Figure 5. 1 An Example Question

We were interested in changing the format of the lessons in appreciation of research trends in mathematics education changing over time and where the focus of the learning paradigm moves from teacher-centred with knowledge transfer to student-centred with knowledge construction (Baxter and Williams, 2010). This focus is based on constructivist ideas who claim that learning happens when students construct their own knowledge through a series of activities involving thinking about knowledge that has already been owned (Windschitl, 2002). In other words, students become active learners, while teachers act more as facilitators to provide support and challenge in order that students learn optimally (NCTM, 2000; Abrahamson and Kapur, 2018). Through this independent discovery learning, the students engaged in the activities on worksheets that were differentiated according to the student ability. The higher ability students (Sets 1 and 2) were challenged by concepts that consisted of rich and sophisticated problems within the percentage topic. The lower ability students, (Sets 3-5), who were not sufficiently fluent, were provided with guided answers to support their consolidation of their understanding before moving on to the next question. While monitoring student engagement with the activities, we recognised that some middle-and lower-ability students took longer than expected to show fully worked solutions to their questions. This longer working time meant that students persevered with the questions and that they really wanted to show solutions and achieve full marks. It was an important discovery for the students to appreciate that taking a long time to finish something is not a sign of poor skills but rather a sign of determination to complete a complex problem.

A few minutes into the independent questions, two students (Alex and Dakota) from the middle ability groups had their hands up and were asking for explanations on how to answer the questions from Figure 5.1. They claimed that they did not know what they had to do. In a conversation with one of the students, Dakota, it became clear that the student did not even know how to start the question and the previous explanations and guided steps did not support both of them. I further observed Dakota making use of avoidance techniques, to shield his uncertainty over how to cope when outside his 'normal support structure'. The second student, Alex, attempted to start the question but had a 'blockage', as he stated '*I know that I need to find 10% first but then I don't know what to do next* ', and just did not want to continue. When I suggested they read the question again before they started with the solving of the questions and answers they told me that, they just '*want to complete it and get it over with'*. This statement from the students showed to me that I am just teaching mathematics to students to answer questions with no engagement to the 'beauty' or joy of mathematics. Skemp (1976, p.21) explain that instrumental understanding is "rules without reasons'', in other words learning procedures without conceptual understanding and these students who lack confidence can only relate to this approach.

One observation I made from this comment that supported me in my future planning of interventions was that I needed to look at ways of managing a change of expectations of these students. Their past expectation of being able to ask the teacher for help when they became 'stuck' was no longer the way I wanted them to operate but they needed to enjoy mathematics and the learning of it. Enjoyment may come from activities that are seen as 'real' and those that they can share with peers. The student focus group interviews had indicated that many students enjoyed the hands-on engaged activities of the task even if this hands-on did not represent a real-life shop. For example, Dakota had stated, "*... I ... like to have …lessons…measuring stuff ...but ...outside of classes to make it funner*." And Sam had commented on the opportunity to work with peers saying, "…i*t's good that everyone's mixed, but when we do group work ...it's nice if teacher would let you, like, go with your friends because you tend to have more fun time learning*." My observation notes from this

Phase One classroom session indicated that when students work together and are proactive by dealing with problems themselves instead of asking an adult for help, they are encouraged to be determined and persevere.

Furthermore, during the progress of the first action research cycle intervention lesson, the higher ability students (Ray, Sam, Roan and Julian) finished their assigned task in less than 15 minutes and offered to support the middle-and low-ability students. This peer teaching was not planned for, but it worked very well because peer interactions and the influence students have on each other when they are teaching subject content provides a positive opportunity to examine the emerging development of self-confidence (Bruno et al., 2016). Newbury and Heiner (2012) defined peer teaching as a teaching system in which students cooperate with each other. One of them (peer teacher) conveys knowledge and skills that he/she has mastered to other students (peer student) under the supervision of the teacher. Kaur et al (2011) reported that peer teaching is an interactive approach including two students. Therefore, the high ability students sat next to the middle-and low-ability student and explained the question and the steps for solving it. One area that I felt could be improved upon was the link to *real-life application* of the mathematics, which Ms Hanekom also mentioned in our debriefing session. We observed (during the shop activity) that the students did not get excited about numbers and formulas the way they get excited about history, science, languages, or other subjects that are easier to personally connect to. They see mathematics as abstract and irrelevant figures that are difficult to understand. However, Korner and Hopf (2015) stated that peer teaching is a crucial strategy for achievement therefore, peer teaching supported the outline for the next intervention.

5.3 Intervention Two: Targeted Individual Lessons

Topic: Geometry

Title: Circles and Angles

Focus: Active engagement; Two boys (Dakota and Alex) who struggled in first intervention; link to Chapter Two, section 2.4.3.1(Sociocultural views on learning)

Protocols:

<u>The 10 students</u>:

- Hands-on engaged activity around the school, searching for circular objects;
- Pair /group work during main activity

<u>Teachers:</u>

- I shared information directly with students to anticipate and eliminate misunderstandings;
- Ms Hanekom and I taking feedback from the starter activity;
- No help given to students during the main activity;
- Discussions with students to gauge their views on the activities.

Post lesson reflection: Real-life application and Peer teaching: I observed that the students often did not notice when they are using mathematics in real-life scenarios. Ms Hanekom and I discussed that many of the students lacked perseverance when they came across a 'blockage'.

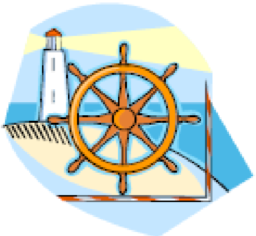
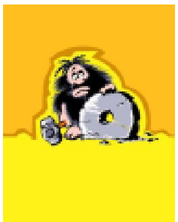
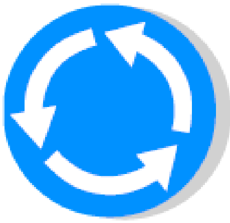
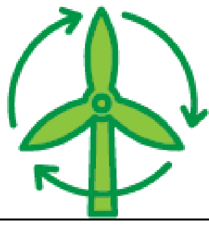
Dominant theme: Engagement in real-life application

Recommendations for action (post lesson): Students lacked perseverance and clarifying meanings of the key terms.

Based on our reflections from the first intervention lesson, I wanted to make sure the second lesson was based around peer teaching as an active engaged learning activity that support students' achievement (Durlak et al., 2011). The Jacobs (2020) SEMISM identifies that in the meso level, the teacher provides strategies for learning and engages the students with real-life mathematics. Therefore, the Jacobs (2020) SEMISM can be a guide for teachers to understand the interrelatedness of actions beyond just the micro-level that also impact students' behaviour. I shared information directly with students to anticipate and eliminate misunderstandings. The lesson developed around a starter, a differentiated main activity for all groups, and a plenary session to summarise the learning that happened.

Following the introduction of the objectives, I explained that as a starter to the lesson I expected them to undertake the following: *Go out of the class for five minutes to identify circular objects and write them down. The most important aspect was the time because they needed to keep to the time frame of five minutes.* We wanted to establish a 'classroom culture' where students are allocated a certain amount of time to complete an activity/exercise but also to inform students that adhering to time limits is part of the learning process and a life skill. This activity was very *hands-on* and *engaged* as all students took part as soon as we set them off. We watched the students as they ran around the school and classroom in search of circular objects. After five minutes, most of the students were back in the room and only two students (Alex and Dakota) came in a few seconds later, because they actually went to the Astroturf and tennis courts, which were a distance away, in search of circular objects. These students should be praised for taking initiative but as we set a time to be back, they clearly prioritised the activity over the time constraint. We spent a short time on taking feedback from the students, as we needed a 'chunk' of time for the main activity, and all groups were sharing their 'collected' circular objects enthusiastically.

I explained to the students what I expected them to achieve and set them the task displayed in Figure 5.2 (a) and (b), the worksheet consisted of 24 cards of illustrated real-life circle problems.

1. Circumference of a tyre of radius 12 inches 	2. Circumference of a ship's wheel of radius75cm 	3. Circumference of a steering wheel of diameter 45cm
4. Circumference of a cart wheel of radius 1.2m 	5. Circumference of a roulette wheel of diameter 47cm 	6. Circumference of a children's roundabout of diameter 4.7m 
7. Area of a stone wheel of radius 63cm 	8. Area of a circular traffic island of radius 12.5m 	9. Cross-sectional area of the earth with radius 6371km 
10. Area of glass on a blood pressure monitor with diameter 7inches 	11. Length of a wind turbine blade when its "sweep" area is a circle 706.9m^2 	12. Length of the minute hand on a clock whose circumference is 65.97cm. 

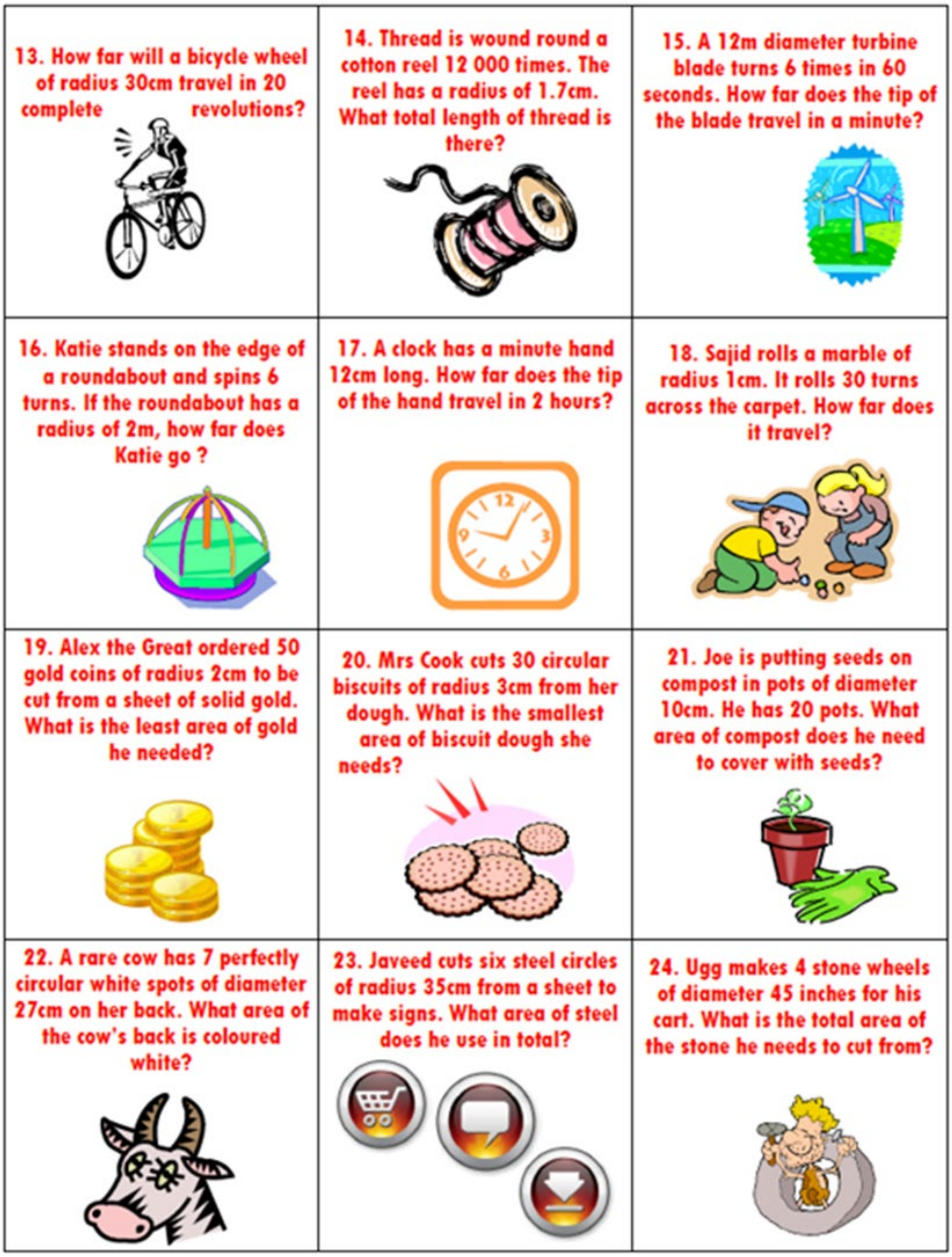


Figure 5. 2 (a) and (b) Intervention Task Two

There were a) mixed questions of moderate challenge requiring students to choose the correct formula and use the correct number (sometimes the radius was given, sometimes the diameter, for example cards 1-10); b) medium difficulty require students to reverse the formula to find radius/diameter, for example 11 and 12 and c) 12 more wordy exercises that needed to be interpreted carefully to understand the situation were included (for example, 13-24). The students then needed to choose the correct formula and apply to solve the problem posed.

Dakota was a student who I felt demonstrated low levels of self-concept because his ability in mathematics was low and his comments during the focus group interviews identified that he did not enjoy and have an interest in mathematics, which is an important factor in mathematics education. Alex and Dakota were confident in reading the time on a mobile phone or a wristwatch but as they were focused on completing the activity, which was hands-on, they 'ignored' the time allowed.

Their next step was finding a question from the sheet to work through as a pair. Alex said he cycled to school every day, but Dakota's mother drops him off and picks him up after school and therefore, Alex was more aware of circular shapes, for example, the wheels on his bicycle. Alex was smiling and talking with confidence when helping Dakota. He (Alex) later said that he often got to cycle, at a cycle park near his home with his friends and often helps his friends with fixing punctures on their bikes and therefore question 13 on the worksheet attracted his attention. Following the previous negativity from Dakota, I was pleased to see that he was engaged with this task. I assumed this may be due to the task relating closely to experiences his friend, Alex, had in his life and he was confident that he could successfully complete it with the help from Alex. He later commented in his verbal feedback to Ms Hanekom '*It was good working in pairs as Alex and I discussed and worked well together, I didn't get* *it, but Alex was able to tell me what to do*.' This comment was also evident from the focus group interviews where three students stated:

> **HA:** … do a bit more … group work instead of … just being in pairs and reading from the book. So, do … more of a group, teamwork, kind of, challenge thing…
>
> **RO**: … I agree with…working in groups, tackling the challenges all together. Because sometimes someone might have... Be better off doing something or let them teach each other...
>
> **AL:** …go into groups for revision, this is like going to groups and … have questions … quiz questions…

The comments, above, states that the students preferred to work in groups as this supported their learning and reflects the findings of Carter and Darling-Hammond (2016) and Lee (2017) who suggests that students are more engaged if they see the relevance of the task when teachers incorporate knowledge and skill bases for their students and the communities from which they come from.

Dakota is also a hard-working student who always does his best to complete a task, using the quickest way possible. Getting a good grade seems to be important to him. My observations of him indicate that he aims for what Skemp (2006) describes as an instrumental understanding of the concepts being studied; he wants to know how to do something not why it works. Therefore, Dakota's interest in the instrumental (procedural) method was easier for him to pick up. It provided him with rules to get the right answers, and at times a reward for arriving at the correct answer quickly. The risk? It does not promote a deeper understanding of mathematics as found in the relational (connected) approach where what is learnt can be adapted to new tasks, as it becomes easier to remember, and exists on an intuitive, organic level.

A lot of the questions were real-life problems, where the students had the opportunity to participate fully within the group, use the mini whiteboards as they became 'messy' with the solutions therefore, requiring the students to grapple with a number of issues in order to solve them. The students were all engaged during this activity, demonstrating Goodall (2013) proposal that students are more engaged if they see the relevance of the task.

Once the students completed the task, Ms Hanekom and I asked for feedback from all the groups. All the higher ability students completed their questions correctly. Both groups of middle-and low- ability students struggled with the terminology of the statements (such as, cross-sectional area, traffic island); both of these groups of students did not know how to work through the questions or the formula and the middle-ability students attempted some of the challenging reverse questions but at certain stages of their working they encountered a blockage, as shown in Figure 5. 3, and left the next steps out.

Group	**Strengths**	**Areas of weakness**
High ability		
Middle ability	Interpret visual activities well to understand geometric concepts (Guzman, 2008)	Confusing circumference of circle with area of circle. Analysing complex information in a question to draw conclusions about what the question asks. Not familiar with the number π (3.14), formulae for circles: πr^2 and $2\pi r$
Low ability	Interpret visual activities well to understand geometric concepts (Guzman, 2008)	Confusing circumference of circle with area of circle. Analysing complex information in a question to draw conclusions about what the question asks. Difficulty in reading the worded questions. Weakness in the language of Geometry Not familiar with the number π (3.14), formulae for circles: πr^2 and $2\pi r$

Figure 5. 3 Feedback - Strengths and Weaknesses

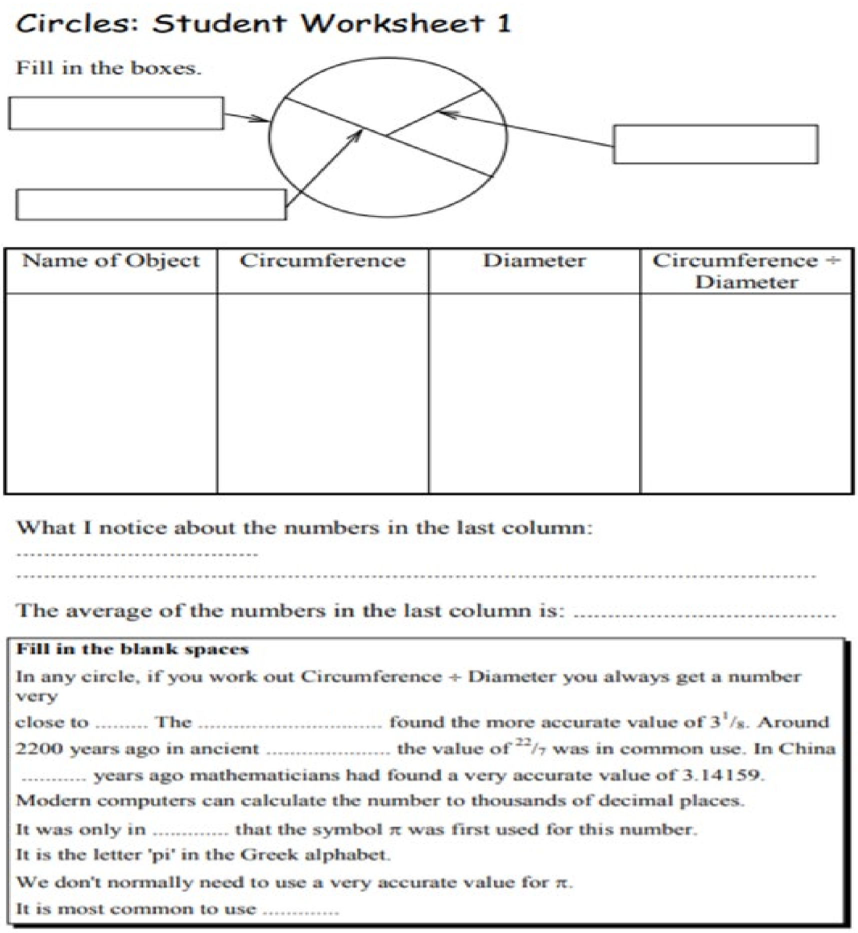
Figure 5.3 displayed to Ms Hanekom and me that the low ability students struggled with the worded questions and only answered or attempted a few of the picture questions. Figure 5.4 illustrates the feedback form used when students gave feedback to each other.

Name:	Ray Samaai	Target in mathematics	5b
Date:	12 June 2016		
What went well:	Clear understanding of basic Numeracy, calculation with two digit and three-digit numbers. Multiplication and division up to and including with three digits and two digits. Clear understanding of basic algebra		
Even better if:	Focussed work on class and undertaking independent learning at home. Practice and consolidation needed with geometry, advanced algebra and handling data concepts.		
The activity-feedback:	Further develop the use of fractions with different denominators and in all calculations and relate this to real life mathematics. Use the MyMaths website as support.		

Figure 5. 4 Feedback Form Used With Students

The feedback form, Figure 5.5, was given to students to complete which allowed them to reflect on their learning, to clarify areas where they needed to improve, and it also provided them with the opportunity to self-assess their skills and capabilities.

The next stage of the intervention was for me to assign the students in pairs, for example, a high ability student would be paired with a middle or low ability student. This support was needed to re-design the dynamics of the groups and to introduce the peer teaching. Peer teaching can be described as an instructional system in which students teach other students (Kaur et al., 2011). The peer teaching approach can be used to aid in the instruction of a few specific students (in this case, middle- and low-ability) or on a class-wide basis (Newbury and Heiner, 2012). The strategy is used as a supplement to teacher-directed instruction in the classroom and it is not meant to replace it. Peer teaching has been extremely powerful as a way of improving student academic, social, and behavioural functioning that goes beyond typical teacher-directed instruction (Spencer, 2006). When implemented in addition to teacher-directed instruction in this study, peer teaching led to a decrease and/or prevention of anti-social behaviour more than only teacher-directed instruction. Figure 5.5 (below) explains the task that each student of middle-or low-ability had to attempt to solve with a student of higher ability.


Circles: Student Worksheet 1

Fill in the boxes.

Name of Object	Circumference	Diameter	Circumference ÷ Diameter

What I notice about the numbers in the last column: ....
....

The average of the numbers in the last column is: ....

Fill in the blank spaces

In any circle, if you work out Circumference ÷ Diameter you always get a number very close to .... The .... found the more accurate value of $3^1/_8$. Around 2200 years ago in ancient .... the value of $^{22}/_7$ was in common use. In China .... years ago mathematicians had found a very accurate value of 3.14159.
Modern computers can calculate the number to thousands of decimal places.
It was only in .... that the symbol π was first used for this number.
It is the letter 'pi' in the Greek alphabet.
We don't normally need to use a very accurate value for π.
It is most common to use ....

Figure 5. 5 Peer Teaching Worksheet

The main features from the two tasks were that they related to real-life problems that kept the students actively engaged and that peer teaching focused on individualised support for weaker students. Mitchell and Beresford (2014) notes that peer teaching supports weaker students and helps to build confidence and consolidate knowledge. Using real-life problems in mathematics classrooms places extra demands on teachers and students that needs to be addressed. Ms Hanekom and I needed to consider at least two dimensions related to classroom teaching when we planned and taught real-life problems. One was the complexity (intensity or grade) of reality that we thought was appropriate to import into the intervention classroom and the other was, the methods used to learn and work with real-life problems. They also kept the practical perspective on each dimension. In England, the newly revised national curriculum effective in 2015 identifies problem-solving as one of the main aims of the mathematics curriculum. The national curriculum specifies *modelling situations mathematically* and in*terpreting and solving problems including financial contexts* as targets of instruction. These aims have close connotations to real world connections (DfE, 2013). Solving real-life problems led to a typical decision situation where students asked: '*Should we stop working on our problem now? Do we have enough information to solve the real-life problem*?' These were not typical questions asked in the intervention lessons but what the students learnt when they solved the real-life problems was that an exact calculation is not enough for a good solution. For example, they learnt to write down mathematical terminology to describe the situation; they did calculations; interpreted the results of the calculation; improved the quality of the process in finding the solution; re-calculated (several times if needed); and discussed the results with others at their table. Finally, yet importantly, they reflected on the solution process in order to learn for the future. For the next intervention, Mason and Davis (1991) stated that it is important to recognise being stuck and to acknowledge it, therefore, I planned to explore how to support students when they '*get stuck*' and started to explore strategies for helping them to become '*unstuck*' and persevere when faced with challenging mathematics.

Today, teachers are under pressure to raise test and examination scores. A 'data driven' mindset has become far too common in this school. With the pressures of teaching the 'to the test', and intensely monitoring test scores of students, teachers are neglecting to teach critical 21st century work skills required to prepare students for their future success (Scott, 2017). In this section students displayed low levels of self-efficacy and therefore, the focus was on peer-teaching which is an instructional approach. Peer-teaching moved away from a traditional lecture type teaching method to active engagement which allowed students to learn by doing and applying ideas to a given task or project. Peer-teaching involved students applying what they have learnt in the classroom to solve real problems and produce results that matter. Peer-learning gave the teachers an opportunity to teach, observe and evaluate real-world skills, and focused on the education of students, not on the curriculum (Chen, and Yang, 2019). It has been my experience, in my twenty years teaching experience, that the layout of peer-teaching must be organised and structured for the students to accommodate social collaboration in a cooperative learning environment, and an openness to respect the opinions, thoughts and ideas of their fellow classmates.

5.4 Intervention Three: Real-life Application and Peer Tutoring

Topic: Handling Data

Title: Collect and analyse numerical data

Focus: Address perseverance and 'in-the-moment struggles', clarifying the meanings of the key terms to support students' statistical concepts. Chapter two, section 2.3.1

Protocols:

The 10 students:

- Starter - given worksheet to complete to gather information from peers;
- Gather meaning about the real world;
- Individual data collection
- Group activity – completing the table

Teachers:

- I engaged students with a starter and to check prior learning;
- Observe students' communication and engagement with each other;
- I explained the individual activity to students;
- I focussed on two higher and two low ability students during the second activity
- Ms Hanekom discussed the second activity with Roan (low ability student)
- I prepared statements of a fictious person and asked one student to read it
- Ms Hanekom led the final activity

Post lesson reflection: Active engagement was the primary aim, with teachers' input. By having to think about the techniques and strategies to employ and how Ms Hanekom and I could positively impact on the students, we needed to incorporate perseverance and purpose throughout each activity.

Dominant theme (s): Active engagement

Recommendations for action (post lesson): Use of technology

As part of the GCSE examinations, students are often required to give reasons behind their answers, something they are not always very confident in doing. My hypothesis is that in the past they have been given an instrumental understanding of these topics and as a result they are unable to mathematise (Wheeler, 1982). Therefore, in this lesson Ms Hanekom and I engaged the students with real life active activities to gain new knowledge.

I started the session with an activity to gather information on how students would collect data in a chronological order and to check their prior learning. The students went around the class and engaged with each other through the questioning to complete their worksheet. The blank cells in Figure 5.6 were filled in with any other interesting facts they could find out from other students, for example, pets (yes or no), siblings (yes or no), favourite porridge, and favourite movie. This active engagement gave Ms Hanekom and me the opportunity to observe the students and how they communicated with each other. During this real-life activity the students were constructing meaning about the world around them, through generating new knowledge, understanding about the real world every day and how to sort and record data (Protheroe, 2007).

Figure 5.7 illustrates the activity the students had to complete in five minutes. Thus, the starter activity engaged the students to think about their data collecting methods and how they would approach each question.

Data Collection Starter

1. You want to find out which students in the school have pets. Which question below is best to ask people and why?

How many pets do you have?

DO YOU HAVE A CAT OR A DOG AS A PET?

Why do you like gerbils?

Do you have a cat, a dog or something else as a pet?

2. Of the groups of students below, who might be best to ask to get an overview of the whole school and why?

All of Year 9

Everyone in the dining hall at break

A random student from each tutor group

Everyone in the school

3. Which of the formats below should you use to collect your answers?

Name	Number of cats	Number of dogs	Number of other pets

Number of cats	Number of dogs	Number of other pets

Number of pets	Tally	Frequency
0		
1		
2		
3+		

Figure 5. 6 Data Collection Starter Activity

In Figure 5.6, the starter was used to discuss methods of data collection, and after the starter, I explained to the students that they now needed to go around the class to collect data by themselves. Figure 5.7 was used for the individual collection of the data.

Name	Age	Height	Favourite Colour				

Figure 5. 7 Individual Student Data Collection Sheet

For the first part of the task, I positioned myself so I could observe two higher attaining and two lower attaining students within the class. Julian and Roan are two hardworking students who participate well in lessons and attended additional support sessions when they felt extra help is required. They are students who achieved well in assessments as a result of hard work and memorising techniques; they did not seem to want to know why something works, only how to get the answer right. From discussions I have had with them they know that with hard work you can get better at mathematics.

After examining the sheet, Julian asked Roan for clarification that the frequency column is the tally marks written as numerals (numbers). Roan agreed with Julian and said that because of this it would be easy to complete the worksheet. During the activity both students remained engaged on the task and were able to conclude and agree on their answers through a logical process. They were able to communicate their understanding to each other and were not afraid to question the other person's logic. When questioned, they listened to the reasons behind the other person's disagreement with them. Reflecting on this task in her conversation with Ms Hanekom, Roan stated that she had found the task easy to do once they had worked out what each tally section represented. Julian also commented that the task was easy although it was a bit challenging for a few of the questions involved further discussions, as clarification on question one and three was needed to help their understanding.

At the same time as this, Gray and Logan were working together on the task. They are lower attaining students within the group and have a different approach to each other in their work in mathematics. Logan gives up quickly when he encounters a difficulty whereas Gray will always put down an answer, even if it is a guess. Very soon after the sheet was given out, Gray asked me what they had to do. I reminded her, then she quickly asked how they were meant to do it. I suggested they both had to decide what the tally marks mean and also what she needed to write in the frequency columns.

Gray said that the tally marks column must be written in numbers to which Logan differed and stated that the numbers must be in the frequency columns. Both students looked again at the worksheet and decided that they needed further clarification, and they agreed on the tally marks and frequency columns. Logan agreed, without debate, and they wrote their answers down. When it came to deciding on the last two questions, Logan had lost interest in the task and left Gray to complete it. Thus, while observing the students I noticed that Gray and Logan had 'in-the-moment struggles' to achieve deep mathematical understandings and although Gray persevered Logan gave up on the questions. Here, the idea of struggle does not imply unneeded frustration with extreme challenges. Instead, struggle refers to the productive action of wrestling with key mathematical ideas that are within reach, but not yet well formed (Hiebert et al., 1996). Perseverance has long been recognized as vital to the learning process because students must experience and overcome 'struggles and barriers' to be successful. Moreover, Pólya (2014) described such struggle with key mathematical ideas is a natural part of doing mathematics: learning with understanding requires exploring different problem-solving strategies to help reveal and refine connections among ideas. In all, persevering to overcome struggles is logically related to learning mathematics with understanding. If mathematical understanding is mental connections among facts, ideas, and procedures, then struggling is a process that happens in-the-moment to re-form these connections when old connections are found to be inadequate to make sense of a new problem (Hiebert and Grouws, 2007).

In preparation for the lesson, I prepared some statements linked to a person called James. The statements are shown in Figure 5.8, and I asked one of the students to read the statements to the rest of the group.

- James lives in Birmingham.
- James was born in Exeter.
- James is 43 years old.
- James is married.
- James and his wife have 3 children.
- James is an engineer.
- James is tall; his height is about 194 cm.
- James weighs 96 kg.
- James owns a car.
- James' favourite rock group is Led Zeppelin.

Figure 5. 8 Teacher Statements to the Lesson

Following the reading, I discussed with students how they could present the data under headings in a table. As a group we came up with Table 5.3.

Table 5. 3 Presentation of Data for James

Questions/Headings	**Answers/Data**
Place of residence	Birmingham
Birthplace	Exeter
Age (years)	43
Married	Yes
Children	3
Profession	Engineer
Height	194cm
Weight	96kg
Car	Yes
Music	Led Zepplin

The students then copied the table into their exercise books, and this took a further five minutes. Copying the table gave the students an example to refer to later in the session when they needed help (and for their normal mathematics lessons) but also when they revise for assessments they can look back at their example. The use of examples by teachers in the mathematics classroom is a well-established practice. Research into how teachers integrate examples into their teaching remains scarce (Zodik and Zaslavsky, 2008). The significance of examples is summarised by Watson and Mason (2006: p. 39): "learning mathematics can be seen as a process of generalising from specific examples". Examples are therefore paramount in mathematical teaching and learning.

Afterwards the students and I discussed with the students as a group and discovered what numerical data was and what data from the table could be classed as numerical data. I introduced the types of data, through concepts, such as quantitative, discrete and continuous data. This part of the lesson linked with their first collection of data. I used Table 5.3 to ask the students to tell me which of those headings were: quantitative, discrete or continuous data. I focused my attention on the students from the middle-and low-ability sets (Dakota, Hayden, Logan, Alex, Brook and Roan) because they needed more support. In the second intervention session, students from the middle-and low-ability sets were struggling with the terminology in mathematics and therefore I decided to focus more attention on clarifying the meanings of the key terms to them and support them with these statistical concepts.

Ms Hanekom led the final part of the session, and this covered the students' engagement with statistics for the future. Ms Hanekom displayed Figure 5.9 on the interactive whiteboard. The figure demonstrated information about obesity, a topic that is currently under discussion in many UK schools.

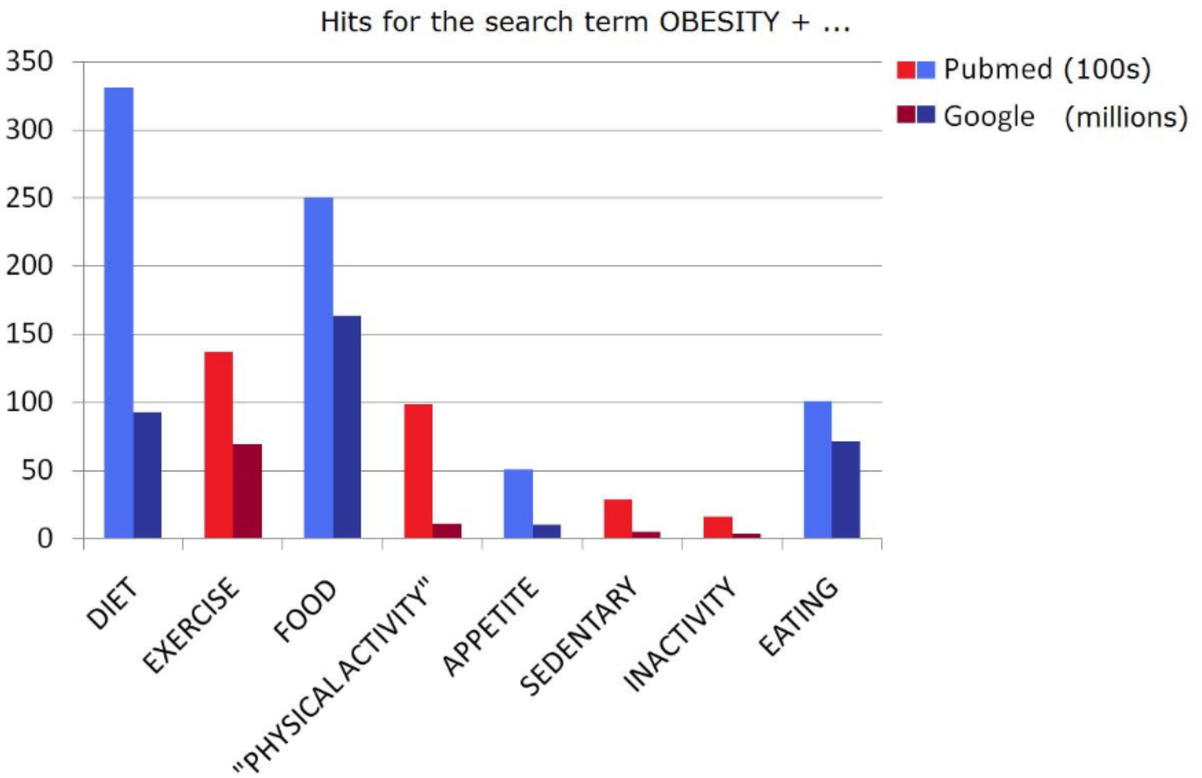


Figure 5. 9 Obesity Information Displayed

Ms Hanekom knew that being proficient at mathematics was more than following a series of steps and memorising formulas. Students were asked to communicate about the mathematics they are studying and justifying their reasoning to classmates. In order to communicate their thinking to others, students naturally reflect on their learning and organise and consolidate their thinking about the mathematics logically (Bray, 2011). Therefore, Ms Hanekom, focused on student understanding that could help and support students learn mathematics better by teaching through a problem-solving approach and questioning the students as to what they could tell her about the image.

The students were quick to respond and said that they 'see different categories' and 'names of search engines'. She related the answers from the students to what conclusions they could come up with regarding the different categories and why only those two search engines. The students were asked to talk at their tables for three minutes, while Ms Hanekom and I walked around and listened to discussions. After the three minutes, Ms Hanekom took feedback and further challenged some answers for clarity. For example, when Brook said "*Google*" is the most important search engine, Ms Hanekom was quick to say; "*Really? Why*?" Many hands were raised, and a further discussion evolved. The answers the students were providing showed that through the mathematical discussion with Ms Hanekom and their peers, they were able to develop their understanding of the topic which would provide a rich foundation for future learning.

On reflection, this intervention was perhaps the first step to move the group forward in creating a positive stance to mathematical learning because it would develop the culture in the intervention class and the students' mathematics classrooms so that students are encouraged to develop as independent mathematicians with strong problem-solving skills. This was important, as we knew that independent problem-solving skills are essential for students for 21st century life and work. Through the student engagement, observation in the lesson and student comments, I gained a good understanding of the weaknesses of students within this group such as terminology of key statistical terms and interpretation of data. Developing the language of mathematics is an essential aspect of teaching mathematics, and research shows that language is a pivotal component of mathematics success (Seethaler et al., 2011), and a student's general knowledge of mathematical vocabulary can predict mathematical performance (van der Walt, 2009).

In this section the students worked very well when given an engaged activity (going around the classroom and questions their peers) and when we all worked together on completing the table. The biggest barrier at this point remained students giving up when they encountered 'in-the-moment-struggles' or difficulties (for example, Gray and Logan); they seemed to lack the ability to persevere and look for alternative ways to solve a problem. The majority were able to start positively on a task and seemed to want to improve but as soon as they came across failure, or perceived failure, they lost interest in the task and stopped. For this reason, I planned the next intervention so that it allowed students to succeed no matter how far they got with the task.

5.5 Intervention Four: Technology Enhanced Learning

Topic: Geometry (patterns) and Algebra straight line graphs)

Title: Technology Use in mathematics

Focus: To develop strategies for how to deal with 'getting stuck' and to encourage the students to persevere when they encounter difficulties.
To develop students' skills in spotting patterns and generalising and testing out their generalisations.
To use mathematical terminology correct

Protocols:

<u>The 10 students</u>:

- Engaged in listening to scenario and answered questions
- Listen to instructions on what to do when they log on to the computers
- To develop rules and check if those rules work
- Used 'think pair share' technique
- After activity three split into two groups by ability

<u>Teachers:</u>

- I consulted the mathematics department at Majac Secondary School regarding the use of Information Technology (ICT)
- I prepared and installed software needed for the session before the lesson took place
- I explained mathematical terminology to students, for example, conjecture
- I questioned students on their geometric conjecture
- Ms Hanekom and I observed students during the activities and made notes
- Ms Hanekom provided students with guided sheets for the straight-line graph activity
- Ms Hanekom worked with higher ability students after activity three
- I worked with the middle and low ability students after activity three

Post lesson reflection: Observations of students' engagement: Technology use could support students to develop their mathematical skills and perseverance. By having to think about the software programmes to use and the skills and techniques, Ms Hanekom and I made sure that the students were kept engaged and focused on the tasks set. When the students were at a 'blockage' we intervened with some students away from the others. I discovered that the students lacked confidence in their own ability. In the next intervention research cycle, one of the aims would be to increase levels of self-efficacy

Dominant theme (s): perseverance

Recommendations for action (post lesson): to increase levels of self-efficacy

When preparing for this lesson I consulted with many mathematics colleagues at Majac Secondary School as to how they use the dedicated computer room with 25 out of 30 working computers. Many responses were that they seldom do and that when they do, they just let the students go on MyMaths, which is an interactive online teaching and homework subscription website for schools that builds student engagement and consolidates mathematics knowledge. I wanted to use interactive technology to support the students' mathematics engagement and decided MyMaths was not a suitable software package.

In order to provide a context for the body of the lesson I invited the intervention students to imagine they were travelling on a train together with other students on their way to school. I told the story*: One student is finishing off his mathematics homework and struggling to solve some quadratic equations by factorisation. Another student, who has already diligently done her homework, is playing a realistic action video game on her smart phone.* This scenario is, of course, designed to emphasise the stark contrast between the worlds of current (and past) mathematics education at school and the world in which many of our current students live most of their life. The point about modern smart phones and other portable digital technologies is that they are not just phones. They are multi-purpose computers with built-in processors, memory, colour display, audio playback, wireless telephone and broadband communications, Global Positioning System (GPS) and accelerometer sensors, still and video camera with touch screen input, which also run a wide variety of Applications (Apps). These Apps (computer programmes designed to run on a mobile device such as a phone/tablet or watch), are what used to be called computer programs or software. The relevance of this choice of story is that the girl could quite as easily have been using an Internet browser to access mathematical information, discussing her mathematics homework by phone with a friend, using Google Maps and Google Earth to plan a cycle trip, or using a powerful, free, mathematical tool such as Geogebra to explore an interesting mathematical problem (NCETM, 2014).

This scenario lead into the activity I prepared, which took place in the dedicated computer room in the school. Before the students arrived, I made sure that the 10 computers were ready for use and that they had relevant programmes installed that the students would use for the 45-minute session.

The first activity that the students came across had a geometric context; the aim of this activity was for the students to drag a point around the screen and watch the movements of a second point. I introduced the terminology 'conjecture' and 'testing their conjecture' to them as they were asked to make conjectures about the geometric relationship between the pairs of points, they had to add geometric construction lines and notice what transformations they could see and note this down in their exercise books. Figure 5.10 is a screen shot of images that shows the movement of the shape in different formations.

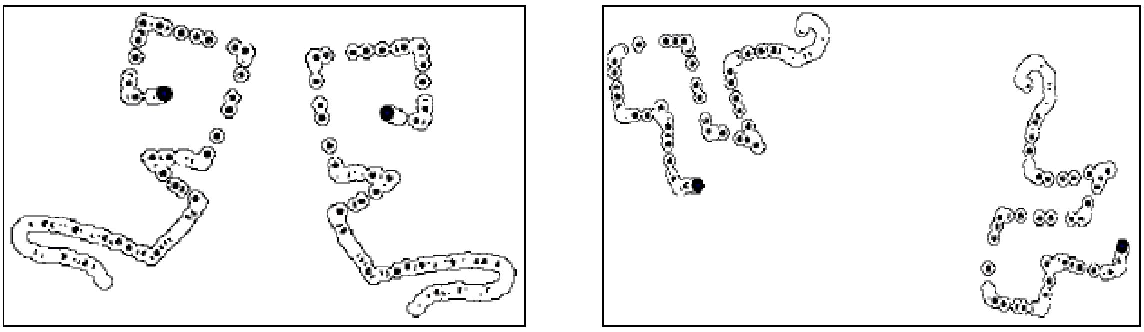


Figure 5. 10 Screen of the Transformation Images

During the first activity, which also was a warmup to the session, the students played around and moved their cursors to drag the point. During the focus group interviews students stated that they would like their teachers to use technology more, for example, Ray stated: *'...go on the computers and watch stuff and ... learn then you can remember it more…'* The students could identify the symmetry, rotation, reflection, enlargement and translation of the original shape. Most of the students immediately engaged with the activity as they were used to playing games on their own digital devices (mobile phones, laptops, tablets). During this activity Ms Hanekom and I observed the student engagement with the activity and noted that the students were all engaged and not one student was off task, for example, speaking to someone else. This interactive engaged learning provided the opportunity for the students to see and interact with mathematical concepts. Students explored and made discoveries with the games, simulations and digital tools.

The second activity involved a semi-structured investigation into straight-line graphs using a dynamic graphing Information Technology package, Desmos. For this intervention I wanted to achieve three things in addition to the curriculum objective. The first was to begin to develop strategies for how to deal with 'getting stuck' and to encourage the students to persevere when they encounter difficulties. Second, to develop students' skills in spotting patterns and generalising and testing out their generalisations to convince themselves and others that their findings were correct and third I wanted the students to gain an understanding of what the '*m*' and '*c*' in the equation y = mx + c represented because they would discover the equation of a straight line was in the form y = mx + c where *m* is the slope of the line and *c* is the y-intercept. The y-intercept of the line is the value of *y* at the point where the line crosses the y-axis. A brief demonstration on how to use the software was followed by the investigation.

I made sure they understood exactly what they needed to achieve. I questioned the students individually and asked them to explain what they did to achieve the particular outcome. Through this questioning, I identified which students understood what they were doing and were ready to move on to the next activity. Before moving on with the task, I reminded the students about the written work on straight-line graphs they had done in previous mathematics lessons, and they needed to discover:

- the y-intercept; the steeper lines have a larger number before the x 3;
- lines that slope down have negative numbers before the x 4; and,
- rules of horizontal and vertical lines.

I further explained that the software was different because it was designed to accept certain inputs and it would provide an output. I wanted the students to spot patterns, developed a rule for what they thought they have found and then test that their rule works. Logan, who was often very negative about investigation work, said it would be better if I showed them what it did instead of '*wasting time working it out for ourselves'*. I dealt with this comment by reminding them that we were developing strategies to use if they get 'stuck' so working it out for themselves was necessary and not a waste of time. Asking the students to brainstorm different strategies for dealing with ‘getting stuck’ was carried out using the ‘think, pair, share’ technique (Wolff et al., 2015). This technique was used to encourage students who lack confidence in sharing their ideas to discuss them with a partner. Initially students have a couple of minutes to think about their response on their own; they then have a couple of minutes to discuss ideas with a partner so they can practise sharing their ideas and get some feedback before sharing with the whole class. Having observed that a large proportion of the group (middle and low ability students) lacked confidence in their mathematical ability, I used this technique frequently and had seen it improve the number of students who are willing to volunteer a response to questions asked to the class.

When I asked the class to share their views the first response was ‘ask the teacher for help’, which was closely followed by ‘ask a friend’. When I asked if anyone had anything else to contribute no-one volunteered. At this point, I asked them to think about ways they could help themselves when they were stuck. After a short time, Sam suggested ‘look at your class notes or read a textbook’. Ray added ‘re-read the question’. I added these to the dry white board so they could refer to it during the course of the lesson.

Ms Hanekom issued each student with a guidance sheet that gave them prompts to support them through the investigation. On this sheet, I briefly explained what they were doing in the task. The first part of the guidance was looking at the effects of changing ‘c’. An extract of this is given below in Figure 5.11

Straight Line Graphs in Desmos

Open www.desmos.com/calculator

1. Use Desmos to plot the following lines on the same axes:
   i. $y = 2x + 1$
   ii. $y = 4x + 1$
   iii. $y = \frac{1}{2}x + 1$
   iv. $y = 5x + 1$

   Print the graph and stick it in your book. Answer the following questions underneath your graph.
   a. What do these lines have in common?
   b. What is the order of steepness? Why do you think that this is the order?
   c. Which line would you expect to be steeper: $y = 2x + 1$ or $y = 6x + 1$? Why?
   d. Which line would you expect to be steeper: $y = x + 1$ or $y = \frac{1}{3}x + 1$? Why?
   Use Desmos to check your answers to c and d.

2. Clear the screen then plot the following lines on the same axes:
   i. $y = 3x + 4$
   ii. $y = 3x + 1$
   iii. $y = 3x - 2$
   iv. $y = 3x$

Print the graph and stick it in your book. Answer the following questions underneath your graph.
   a. What do these lines have in common?
   b. Where do each of the lines cross the y-axis?
   c. Where would the line $y = 3x - 4$ cross the y-axis?
   d. Sketch the graph of $y = 3x - 4$ in your book. Check your answer with Desmos.

Figure 5. 11 The Second Section of the Intervention Used

The worksheet (Figure 5.11) guided students through their own investigations of the straight-line equation y = mx + c, developing an understanding of the effect of varying the 'm' and 'c' on the shape of the graph. This part of the intervention involved a lot of independent thinking, and I purposefully left the guidance from the teacher out. After 15 minutes on this task, I stopped the class and asked for feedback. Ray, Sam, Roan and Julian (high ability students) were able to answer most questions correctly and they came up with conjectures about what happened to the line. Logan, Hayden, Dakota, Gray, Brook and Alex (middle and low ability students) tried, and their progress was notable, but they were mostly on question one. I decided to change the intervention lesson and took the students in the middle and low ability group to one side while Ms Hanekom and the students in the higher-ability group continued to finish question two after which they could move on to the next activity shown in Figure 5.12 below.

Task 2

For the second task you are going to explore what happens when you change the value of 'm' in the equation. By drawing a selection of graphs on the same page explore what happens as 'm' is changed.

Hint: Keep 'c' the same in each graph you draw.

What do you think the rule is?

How are you going to test it?

What happens if 'm' is negative?

Figure 5. 12 Technology Used –Task 2

Figure 5.12 asked the students to undertake investigational work through drawing straight-line graphs and they should explore what happened when '*m*' was changed. The students also needed to answer questions related to their graphs. While Ms Hanekom observed and supported the students in the higher-ability group, I grouped the other students (middle and low ability) around an empty table in the ICT room.

After our discussion of the steps in resolving the problems, the students felt more comfortable to attempt the questions and went back to their computers. Ms Hanekom and I observed the students throughout the activity and went over to question students individually on minor errors they were still making. For the first time in the intervention sessions, I observed how dedicated Alex (a student from the middle ability group) was when he went back to his computer. Alex started immediately to draw on paper his 'problem-solving' ideas and then apply that to his computer assisted programme. I noted the improvement in Alex's confidence and how he engaged with this activity.

After another 20 minutes on this activity, we gathered the group to the tables to summarise what they had achieved in this lesson. The students from the higher ability group quickly talked us through their learning and how they found that task two progressively challenged them but they 'peer taught' each other and then 'it made sense'. The students from the middle and low ability group started to express that at first, they found the second activity very challenging due to the 'groundwork' for this activity not laid out properly in their normal lessons in school. They also admitted that they did not always pay attention when the teacher questioned them and that caused them to not understand what to do.

In terms of Pierce and Stacey's (2010) pedagogical map, this session illustrated opportunities provided by a task that linked numerical and algebraic representations to support classroom interactions where students shared and discussed their thinking. No one was able to complete the second task without some extra guidance provided by the teacher or a peer. When I spoke to the students, when they had an 'in -the-moment struggle', a large proportion (n= 6) of them said it was because they were 'stuck' and unsure what to do. Taking them aside, to a different part in the classroom, for further prompting established that they *did* actually know what to do but they did not think their answer was correct. Therefore, a preliminary finding could be that the biggest barrier that still needed to be overcome was to increase levels of self-efficacy so that the students were not afraid to try something and to reduce the fear of failing. Hence, intervention five would incorporate self-efficacy into the session.

5.6 Intervention Five: Negative Numbers

Topic: Number

Title: Negative Numbers

Focus: To support students reasoning

Protocols:

The 10 students:

- Starter – recapping on strategies for when they 'get stuck'
- Respond to questions as asked
- Worked in groups around their table on their mini whiteboards

Teachers:

- I discussed with students' strategies for when they 'stuck'
- I engaged students through a number on the dry white board
- I shared with students the importance of 'quality of written communication' – GCSE requirement
- Ms Hanekom and I walked around the groups, stopped and talked to students and listening in on mathematical discussions

Observations: students' engagement: Working in pairs and mixed groups can support the increase levels of self-efficacy when the students are able to support each other but once they encounter difficulties, they can quickly loose motivation to continue the task. For this reason, I decided that during the next intervention research cycle I would focus on independent learning and success for all.

Dominant themes: self-efficacy

Recommendations for action (post-lesson): independent learning and success

The intervention working with technology had given the students a confidence boost, so I wanted to use this boost to encourage them to focus on investigating how they make sense of negative numbers, and more specifically what role reasoning played in that process. An example of this type of question is given below:

Find the midpoint between the two number, for example,

- -11 and 5
- -3.5 and -1

This question is worth three marks in the GCSE examination. Students are required to show their workings for this question. Mathematics examination questions are often described as problems that students must solve, rather than as questions that they must answer; I have never heard anyone describe an English Literature question or a geography question in this way. In most subjects I can think of a student having a rough idea of the answer to a question as soon as it is asked and spending their examination time improving this initial answer; in mathematics, on the other hand, I think of a student as tackling a puzzle, trying various approaches until one works, and then producing the answer quite rapidly when the solution is found. From past experience, I know that middle and low ability, students find this type of question challenging, possibly due to the lack of structure in the question. Many middle and low ability students failed to score more than one mark in a similar question because they found it difficult to identify which techniques they had to use. In my professional experience, that comes from years of teaching, this is down to the tendency of mathematics resources to work with only one skill at a time and avoid questions that lack structure and require the use of techniques from different 'chapters' in the textbook. Although many textbooks do now have this style of question towards the end of individual exercises, I have seen the students use avoidance tactics such as slowing down on 'easier' questions so they can avoid having to complete these questions because experience has shown this style of question to be challenging. Before I introduced this intervention, we spent some time recapping the different strategies we could use when we got stuck. Students were able to refer to the 'Stuck Section' on the dry whiteboard and it was clear from the discussion that different students were developing an understanding that they should use this section as their first reference point when 'stuck'. Following this discussion, I presented a problem on the board. I drew a number line on the dry whiteboard, which consisted of end numbers -10 and 10. I asked the students how we would calculate Figure 5.13 (below) using the number line:

$$\boxed{5} + \boxed{-2} + \boxed{-2} + \boxed{-2} = -1$$

$$\boxed{7} + \boxed{-3} - \boxed{5} = -1$$

$$\boxed{-3} - \boxed{-2} = -1$$

Figure 5. 13 Negative Number Question

When I shared the question, I made it clear that at this stage I did not want them to carry out any calculations but instead think about how they were going to tackle this problem. Following this, I asked them to share any ideas they had. Sam explained that if we started at positive five and take two away, we would end up at positive three. I stopped Sam and thanked him for his contribution. I hoped that one of the students from the middle-or low-ability groups would continue but after a few seconds of silence no one raised their hands and therefore, I asked Brook to continue with this problem. Brook stated that if you were at three you needed to take two away and then you will end up with one and from there you will need to take two away and then you will end at minus one. The student's confidence was noticeable, and she hesitated at times, but she persevered and achieved the result.

Following this discussion, we worked through the problem as a class. Students were happy to give ideas as we progressed through it. As we worked through the solution I talked about the requirement for the ‘quality of written communication’ (showing your working) marks in the examination and we looked at different ways we could present our solution, so it was easy to follow and had all that was required to gain these marks.

I then asked the students to work as a group, around their tables, and show me on their mini whiteboards how they would answer the question, shown below:

Consider whether certain values are impossible to find. Could you find integers that would produce all the values from -25 to 25? Would this mean that any value could be found? How could you justify your answer?

I knew that this would be a challenge to the students from the middle- and low-ability groups but I wanted to see how the students attempted the activity, engaged around their tables and if peer learning would happen.

Ms Hanekom and I observed and stopped and talked to groups at certain times, encouraged them, provided support and praised them for effort and perseverance. What I noticed was that the students at all the tables were writing on the mini whiteboards, engaged in learning conversations about the problems. One student often led the conversation and then questions were asked from all the students. After 10 minutes, I asked for feedback and the students responded with what they had written down on their mini whiteboards and notes. They also told me that they had used certain strategies, for example, counting, drawing a full number line from -25 to 25 and that they disagreed with some group members. These responses indicated they were engaged in active learning where students interacted with each other. I explained to the students the steps in solving the problem, answering the questions and some students; mostly the high ability students had most parts of the steps correct. The students from the middle- and low- ability groups attempted the first question and succeeded but left the second part to the questions as this was too challenging.

It seemed that the biggest difficulty at this point was the 'blockage' that occurred; meaning when the students were 'stuck', they called the teacher. The students seemed to lack the confidence to look for alternative ways to solve the problem. The majority were able to start positively on the task and seemed to want to improve but as soon as they came across a challenge or perceived failure, they lost interest in the task and stopped.

We worked on two further questions similar to the previous one. Progress was not always fast, but I found that by reminding students to read the question carefully, and by asking them to discuss what the question was telling them, they were able to have a good attempt at the question. Three different students in the middle and low ability groups commented to Ms Hanekom in conversation that they kept on getting the wrong answers because they did not check their working thoroughly. However, all three also mentioned that because they made this mistake so often in the lesson, they started showing their work in an organised way which helped them to organise their thoughts, which in turn makes them less likely to make a mistake.

After the students answered the two questions, I spoke to Dakota to discuss in more detail his views on this intervention. The first question I asked him was how he found this type of question before we looked at them in class. He mentioned that he did not like them and tried to avoid them as much as possible. I asked him how he did this and he said that he would skip them and move onto the next questions that looked easier. When asked what made a question look easy, he said that an easy question was one that you knew what to do straight away, saying that *'84 - 24'* is easier than saying '*there are eighty-four people on a bus. At the bus stop twenty-four people get off. How many people are on the bus?*' He said the more words there are, the harder it usually is because you need to think harder about what you need to do. He also mentioned that in English, questions are often based on opinions and interpretations so provided you have read the novel you are usually able to come up with an answer but in mathematics, if you cannot work out what you need to do, you need to leave it blank. Dakota also mentioned that in English once you understand the plot and characters it is easy to answer questions but in mathematics, it is all about memorising procedures to follow. If you forget the next step, you are 'stuck'. I asked him how he learnt mathematics at home. He said he usually learns how to do it from a revision guide but knows that it is really better to do many similar questions to help you learn how to use the technique. Interestingly he knew how to work at mathematics, one of the aspects of mathematical resilience but chose not to. Perhaps this was down to him feeling you cannot make a mistake when reading a revision guide but can when doing questions.

I then returned the focus of the informal discussion back to the intervention. I asked Dakota how helpful he found the intervention. He said that when he found out what we were going to do he was dreading it because he could not do this type of questions. However, he did say that reading the questions over carefully and discussing it did help him a lot. He said he felt he was getting better at doing this style of question as the lesson progressed. He said that the most important thing he learnt was when performing addition or subtraction on negative integers he often tends to totally disregard the negative sign which led to the incorrect answer. I asked him if his view of this type of question had now changed. He said he finds them easier now but still does not like them. He would still prefer a question that told you exactly what to do. Although Dakota worked hard, he felt that he would never be good at mathematics. It became clear to me in this informal discussion that he would much rather remain within his comfort zone. However, he was beginning to show that he is willing to leave this comfort zone to allow him to improve, perhaps a sign that he is starting to move towards accepting elements of the intervention 'culture' I am trying to create. My professional judgement was that one of his biggest barriers that he needs to overcome is to move away from trying to gain an instrumental understanding of the work and try to achieve a relational understanding of the topics. It is clear that this is how he operates in other subjects. In English he mentions the need to understand the plot and characters to answer questions but in mathematics he tried to memorise procedures. This is perhaps why he is currently working at two grades lower in mathematics compared to English. The interventions over the six-week period have tried to address this but maybe this time is not long enough to change his mind set and attitude towards mathematics that has been embedded over his previous school years.

Prather and Alibali (2008) pose the question of how people acquire knowledge of principles of arithmetic with negative numbers. Is it a process of detecting and extracting regularities through repeated exposure to operations on negative numbers or do they transfer known principles from operations on positive numbers? Exposure to operations on negative numbers is fairly scarce. For many problems in a school or every-day context it is often possible to find a solution without including negative numbers. Prather and Alibali (2008) used the following task in a study concerning knowledge of principles of arithmetic:

Jane's checking account is overdrawn by £378. This week she deposits her paycheck of £263 and writes a check for her heating account. If her checking account is now overdrawn by £178, how much was her heating bill?

This problem was represented by one student as -378 + 263 – x = -178 and by another as 378 – 263 + x = 178. Both representations are mathematically correct but only the first one involves negative numbers. As the problem is posed there is no mention of negative numbers. In many situations people avoid negatives if they can. The important thing to ask about the exercise is whether the goal is to solve the problem or to develop reasoning with negative numbers.

In this section students worked by themselves and in groups with negative numbers and they focused on solving the problem, individually and as group but 'got stuck' and in doing so the middle and low ability students chose not to continue with certain parts of the questions and they would prefer if questions do not involve negative numbers. Through our observation we noticed that the students easily lost motivation as they did not persevere through the 'in-the-moment-struggle' with questions. Jacobs (2020) SEMISM identifies that in the micro level, it is proximal processes, complex reciprocal interactions between the developing human being and the people, objects and symbols within a micro level, which drive growth. Observation can, perhaps, be viewed as underpinning the proximal processes which occur within the education environment; with careful observation promoting appropriate interventions to support students in fulfilling their developmental potential.

5.7 Intervention Six: Simple Equations

Topic: Algebra

Title: Simple Equations

Focus: Students own success criteria -low threshold, high ceiling tasks

Protocols:

<u>The 10 students</u>:

- Brought class notes and exercises on Basic Algebra with them in this session
- Used their class notes and exercises to support their learning
- Writing algebraic expressions (using numbers and words)
- Teamwork – Algebraic Showdown
- Instructions needed to be read to understand the Showdown
- Did not ask for help during the Showdown

<u>Teachers:</u>

- I led the starter – a ‘guessing game’ (how many paper clips in the pot?
- I engaged through questions on algebra to write numbers and letters
- I introduced the activities one by one
- Ms Hanekom and I observed the students engaged in the activities and how they persevered

Post lesson reflection: Making use of teacher input, active engagement and choice of questions could increase students’ confidence. Focusing on teacher subject knowledge in this lesson through the teacher input supported the students’ success.

Dominant themes: teacher subject knowledge

The sixth lesson was based around the opportunity for the students to complete algebraic learning activities successfully. In the design of this intervention, I wanted to give students the opportunity to complete a low threshold high ceiling task (Boaler, 2015) that allowed them to choose their own success criteria. I wanted to make sure that everyone could succeed and that no one gave up on this task as a result of not being able to get the ‘correct’ solution. I planned the starter to be teacher led to ensure everyone understood the task.

This intervention followed a unit of work on Basic Algebra. In this unit, the class had covered how to write algebraic expressions from words and understand algebraic expressions from words. The students had all covered this unit and they had access to class notes and class work that covered each of these topics for reference with them in the session.

After the starter to the lesson, Figure 5.14 below, I explained to the students that we will take their feedback and then discover if we can find how many paper clips in the pot.

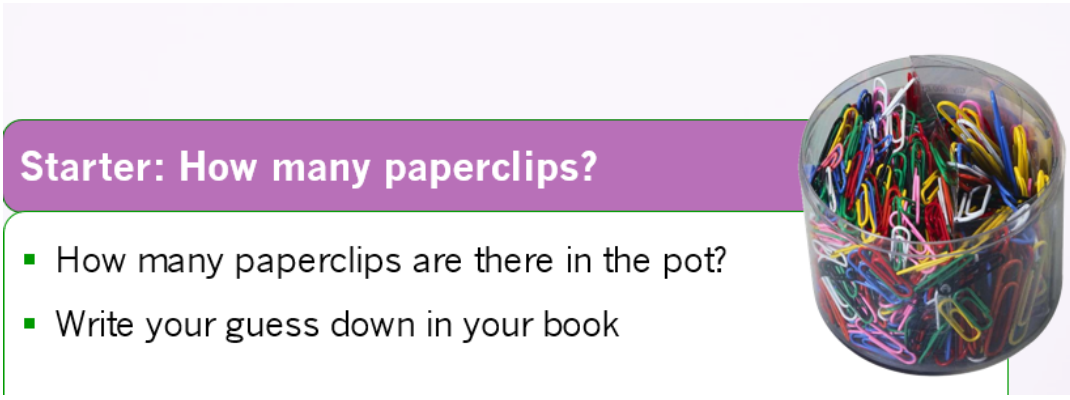


Figure 5. 14 Paperclips Activity

After a short discussion, the students came up with different answers and different views on how they worked out their guesses, for example, Roan stated: '*I have seen this pot before, and it must be a round number like 300 but I am not sure'*. Sam stated: '*my mother used this at home, and I know there should be 550*'. We collaboratively decided that we would work together to see who was correct or even close enough to the answer.

I wrote on the dry wipe board: '*How many paperclips in the pot? =' n*'. The *n* stands for the number of paperclips as we do not know how many in the pot. I then asked a question: '*What if I took 2 out? How would I write this following on from my first answer?'* The students did not know what to respond and I asked them to use their class notes and exercise books and see if they can tell me what the answer could be.

The students went through their notes and Ms Hanekom and I observed them searching and looking at the Basic Algebra notes, but they could come up with what needs to follow. I stepped in (as students were 'stuck' I used my subject knowledge and experience as a teacher to gauge students' understanding) and stated that we would write '*n-2'*. I observed that the middle and low ability students were confused and therefore I used another example, '*if I add three to the pot what will I write down?'*. I could see that the higher ability students' hands were raised and some of the middle ability students tried to respond, and I asked Roan for his response, and he said: '*n+3'*, hesitantly to which I praised him and stated that it is correct. I furthermore asked him to explain how he got his answer and he stated that '*we don't know how many in the pot, that is n but we add three so that will be n +3'*. I observed the smile on his face. This smile showed that he understood, and he was happy with that he correctly told me the answer and that he had courage to say it in front of his peers.

I displayed Figure 5.15 to the students and gave them two minutes to work on it.

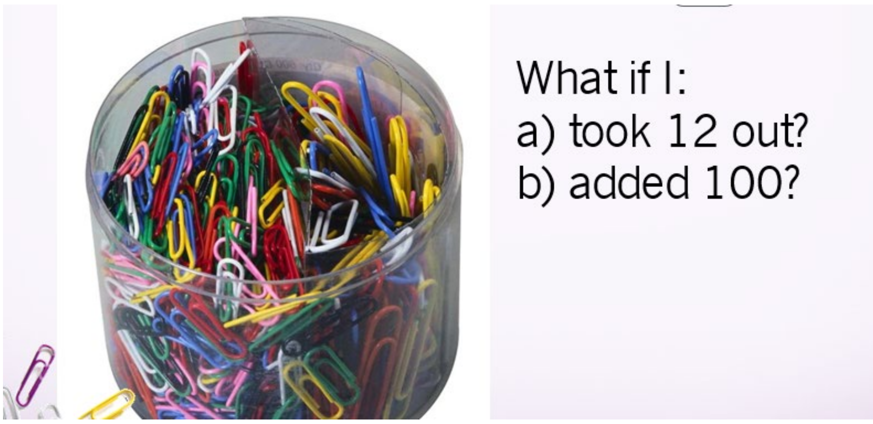
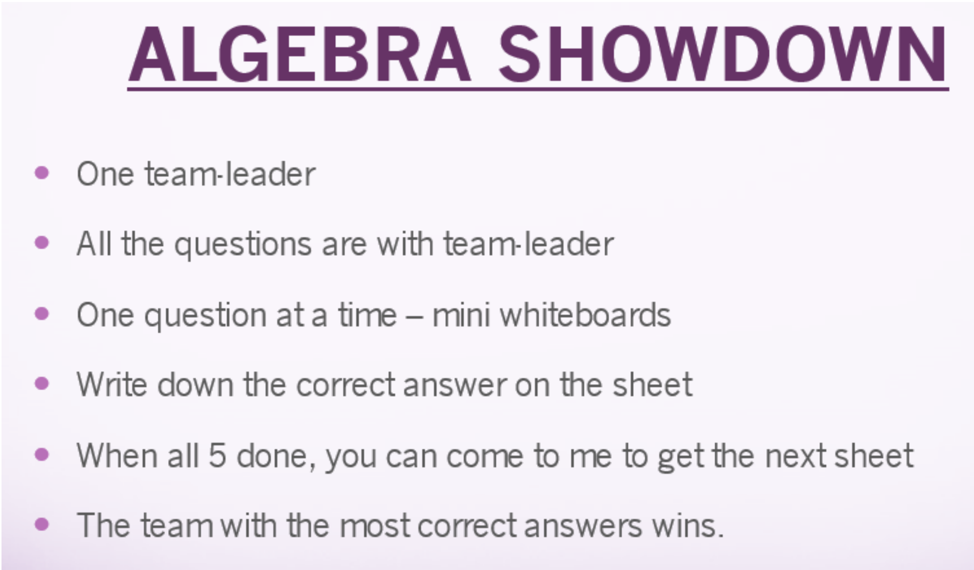


Figure 5. 15 Algebraic Expressions Exercise

Ms Hanekom and I walked around the room and observed that most students knew how to write an algebraic expression and some even smiled at us as we walked pass them, meaning that they are confident in their solutions. After two minutes I took answers from the students and they were all happy with their solutions, all 10 of the students had a correct answer. This showed us that the students understood the concept of writing algebraic expressions.

The next part of the lesson involved an Algebraic Showdown (Figure 5.16 below) where the students needed to work as a team.



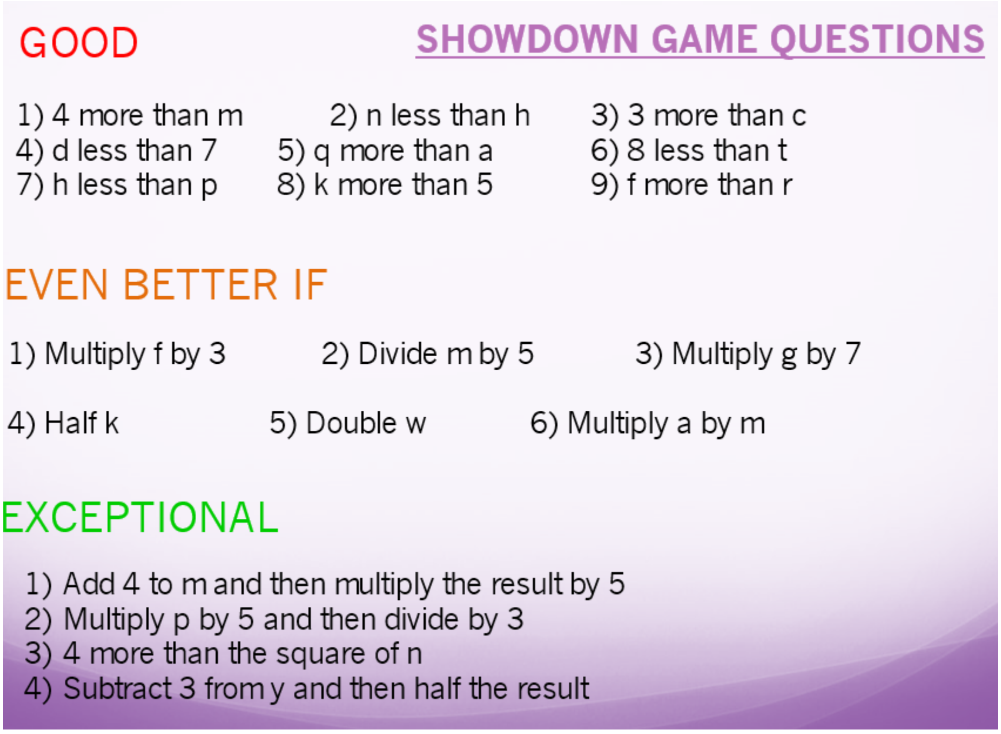


Figure 5. 16 Algebraic Showdown – Team Activity

I gave the students a minute to decide who would be the team leader and it was interesting to see that the leaders were not all from the high ability group students, but Dakota and Alex were also leaders. Dakota and Alex were both popular students at the school and that was no surprise that they put themselves forward to be leaders but also as they can ‘hide’ when certain questions were too challenging. The big emphasis was on referring to their lesson notes and using each other. As Ms Hanekom and I walked around and observed the groups we noticed that there was confusion over which techniques and strategies were suitable for use with the questions, but they persevered and discussed this amongst themselves without asking us for help.

Once the group started to work and I observed they all engaged, I sat down next to Ray and Hayden who were in the same group as Dakota who were all working together on this task. Both of these students were towards the upper and middle end of the class based on attainment but both lacked confidence and felt the need to ask for reassurance along the way. When I started observing, they had decided to start by working out the *even better if* questions from the sheet. They were able to add and subtract (as the examples shown that to them) but they discussed on the multiplication and division questions and Ray led the discussion as he came across these questions in his mathematics classroom lessons before. Ray used his prior learning to support the learning of Hayden and Dakota. They completed the *even better if* questions and moved on to the *exceptional* questions from the sheet. While at the table I observed that Dakota was not talking much, and he listened and at times add a comment to the discussion. Hayden and Ray mostly did the talking and reading the questions to the group. This showed that they worked as a group and discussed their views on the questions and used their mini whiteboards as a resource. When they asked me, I suggested they think about what the question ask them to do at each stage and write this down and then read the question further. They did this and were confident they had used the correct method to calculate the solution.

In this section, we have noticed that the students are not experienced at estimating what size their answers should be. If this became common practice with them then they may become more confident that their answers are correct without the need for reassurance from the teacher. In the conversation with Hayden, he commented that they used the wrong method for the *even better if* questions because they just ‘dived’ into the questions without reading it properly but if they had checked their working thoroughly the answer would have been correct and would have spotted their mistakes earlier without asking me for help.

The students also became over-familiar with assessment questions. If they are asked in an assessment to write questions as algebraic expressions, they would be expected to show their working/writing as I showed them through the examples. This was not the case here, so they were unsure what to do. This is perhaps a sign that students' mathematical experience is being controlled by what they need to know for the 'test'. Dakota mentioned that not reading and understanding what the question asked was the hardest part of the lesson. He said that he was unsure in the *exceptional* questions where to start and then Hayden and Ray helped him to break the sentence down into parts and this made it easier for him to see what to do first. This seems to demonstrate his instrumental understanding of this topic and his developmental level of understanding mathematical terminology (Skemp, 1987).

Many algebraic problems are difficult for students, because solving them may require an understanding of the conceptual aspects of fractions, decimals, negative numbers, equivalence, ratios, percentages, or rates (Stacy and Macgregor, 1999; Stacey and Chick, 2004; Norton and Irvin, 2007). Conceptual understanding consists of knowing the structure or rules of algebra or arithmetic such as the associativity, commutativity, transitivity, and the closure property. For example, students should understand that $\frac{5+2}{7}$ could be separated as $\frac{5}{7} + \frac{2}{7}$ in the same way as they understand the reverse process. Stavy and Tirosh (2000) also perceived a connection between arithmetic and algebra. According to Stavy and Tirosh (2000), students sometimes assume incorrect rules when solving algebra problems. One such rule implies that although the quantities A and B are equal, students incorrectly assume that "more A implies more B". As an example, when they were asked "what is larger, smaller, or equal: $\frac{16y}{8}$ or 2y?" they say that $\frac{16y}{8}$ is larger because it has larger quantities. The Jacobs (2020) SEMISM model acknowledged that the teachers' motivation, PK and SCK in the exo level support the student (micro level) to adopt ways of reasoning to deal with problematic mathematical concepts.

5.8 Summary of Interventions

Each intervention lesson was planned as a cycle of research that built on each other (McNiff, 2010). The outcome of each lesson gave a focus for the next and the learning objective and the tasks were planned with the aim of meeting the new desired outcome. Each lesson was tailored to the needs of the group, which included covering the skills and content required for transition from Year Six to Year Seven in secondary school. In between these six key lessons, the students continued to be taught for four hours per week in their regular mathematics class. During this time, use was made of observing lessons where the intervention students were with a similar focus to the interventions, mostly in line with the 'blockage of being stuck' and what happened in classrooms.

Having now reported on what I observed during the intervention, the next section will report on the key points of the discussions that took place with the mathematics department colleagues at Majac Secondary school after the action research cycle interventions.

While the outcomes indicated an upward shift in students' motivation, self-worth, and psychological well-being, the changes were not significant in terms of grade movement. The outcomes shows that there was little to none improving in students' grades. Some students in the higher-and middle-ability groups (Julian, Roan and Dakota) performed well in the intervention sessions but when they were back in lessons they were not focussed and participating in the lessons. As a result of the interventions and the informal lesson observations, Ms Hanekom and I gave feedback to the mathematics department of our findings about the group and the HoD decided that we must consider the students' end of term assessments, Table 5.4, (pseudonyms are used for anonymity), below. Data was compared before the intervention and after, but the impact could have been the type and style of testing too. Not all improvement is captured in test performance. For example, Ray (a higher-ability student) entered the intervention on a 5c and stayed on a 5c, Alex and Hayden (middle-ability students) made one sub-level progress and none of the lower-ability students progressed to a sub-level or full level.

Table 5. 4 End of Term Levels After Phase One - Intervention One

Surname Forename	Gender	Reg Group	Ethnicity	SEN Status	EAL	Pupil Premium Indicator	Key Stage 2 Banding	KS2 Maths Test Sub Level	Maths Intervention	Maths Level end of term 1
Alex	M	7BS	White - English				Middle	4b	Yes	4a
Ray	M	7AY	White - English				Upper	6c	Yes	6b
Hayden	F	7AW	White - English				Middle	4c	Yes	4b
Julian	F	7BS	White - English			Yes	Upper	5a	Yes	5a
Gray	M	7BS	White Other			Yes	Lower	3b	Yes	3b
Sam	F	7AT	Other White British			Yes	Upper	5c	Yes	5c
Brook	F	7BY	Other White British				Middle	4b	Yes	4b
Roan	F	7BW	Other White British				Upper	6c	Yes	6c
Logan	M	7AT	White - English				Lower	3a	Yes	3a
Dakota	M	7AS	Indian		Yes	Yes	Middle	4a	Yes	4a

Surname Forename	Gender		Ethnicity	SEN Status	EAL	Pupil Premium Indicator	Key Stage 2 Banding	KS2 Maths Test Sub Level	Maths Intervention	Maths Level end of term 1
Alex	M	7BS	White - English				Middle	4b	Yes	4a
Ray	M	7AY	White - English				Upper	6c	Yes	6b
Hayden	F	7AW	White - English				Middle	4c	Yes	4b
Julian	F	7BS	White - English			Yes	Upper	5a	Yes	5a
Gray	M	7BS	White Other			Yes	Lower	3b	Yes	3b

Assessing learning is a crucial part of a teacher's job and is a telling sign of how a student is progressing. Although teachers can see the individual struggles of students in their class, they need a concrete way of identifying and tracking the progress or lack of progress of individual students. Teacher recommendation is often taken into consideration, but test data is necessary to track and monitor the progress of all students (Lembke et al., 2012). If a student is having difficulties in mathematics, assessments should be done to help identify the problems and the reasons behind the problems (Burns et al., 2010).

The progress of the students in the study after the six- week intervention lessons was a 30% gain as three students made a sub-level progress. This minimal gain in progress was disappointing because the aim was to significantly improve the learning outcomes in basic mathematics skills of the students in the study. A motivational learning environment was provided, which emphasised fluency, automatic recall of basic skill information, strategy use and timed and strategic practiced (Baker, Gersten, and Lee, 2002; McMaster, Fuchs, Fuchs, and Compton, 2005).

Whilst this intervention provided proof of concepts for the efficacy of the mathematics curriculum, there were two key limitations. First, the mathematics assessments of Majac Secondary School mathematics department were different from the intervention delivered and the content of the curriculum knowledge assessment was not the focus of the intervention. Therefore, the observed learning gains in the intervention sessions could be attributed, in part, to students' familiarity with the intervention materials and structure as the lessons developed. Second, the mathematics intervention was implemented for a relatively short period of time (six-weeks) as the mathematics department decided the intervention should be reviewed after six -weeks. It is recommended that interventions should be implemented for a minimum of 12 weeks in evaluation research to ascertain the full intervention benefits (Higgins, Xiao, and Katsipataki, 2012). Hence, taking these limitations into consideration, the results from the intervention need to be corroborated with additional studies using standardised based mathematics assessments. Furthermore, to understand why this intervention was effective at supporting the development of early mathematical skills, additional studies are needed to examine underlying cognitive skills (such as non-verbal Intelligence Quotient (IQ), processing speed, receptive vocabulary, verbal memory, and non-verbal memory) that may account for the observed learning gains.

5.9 Chapter Conclusion

This chapter sought to address raising achievement through six intervention lessons through a focus on interactive engagement, motivation and enhanced subject knowledge. Jacobs (2020) SEMISM reflected throughout the different levels: exo, meso and micro, that student involvement in the learning environment enhance their learning. Specifically, in the micro level the student participants with which teachers engaged are observed, cared for and interacted with through the six intervention lessons.

Interactive engagement was at the forefront of each lesson as stated in the focus group interviews. For example, one student suggested, (Chapter 4)

> **HA**: …maybe a bit more interactive lessons…, it's really, when they're, with their friends and they can learn with their friends, but then still be with someone that they hang around with and then, but still have, … They have interactive lessons, but then still be hard … so people can be challenged

Interactive engagement developed through a range of activities that stimulated the students' learning. The engagement in the intervention lessons was critical for providing opportunities to assess students and subsequently address motivation which underpinned the engagement that we observed.

During the Phase One teacher semi-structured interviews, some of the teachers (n=2) reported their perceptions of engagement in conjunction with comments about student achievement. When probed, the teachers also revealed that they were able to make distinctions between how students engaged and how they achieved in mathematics. For example, two teachers stated:

JMM: When they are engaged and interested.
SMA: … when the lesson is engaging from the start …the students want to engage in the lesson and want to do well and maybe adding in a little competition. …if you can engage the students then that's it, you've got them all on board.

This finding is significant because it highlighted the importance of attending to student engagement in addition to achievement. Furthermore, for students who lack engagement, it may be necessary for teachers to prioritise attention towards promoting engagement before improvements in learning outcomes can occur. The six-action research cycle intervention lessons addressed how engagement and motivation can be enhanced in classroom practices. However, what was not clear was to what extent the practices used by teachers at Majac Secondary School were targeted to meet particular motivational needs of individual students or were used because the teachers perceived they promoted student engagement across the whole class. The focus of the practices used appeared to depend on the teacher's knowledge of available practices for motivating students and what they perceived would be effective for promoting learning outcomes for their students. Further investigation of the practice's teachers used for motivating students were required to determine whether or not teachers drew from their experiences, advice from colleagues or pedagogic literature, when making decisions about appropriate and effective practices to use. Following these findings from the Phase One – action research cycle intervention lessons, the next chapter moves on to Phase Two of the study. Phase Two presents the findings and analysis of the project emanating from the final set of student focus group interviews and semi-structured teacher interviews after the six-week intervention with the focus group students.

CHAPTER SIX: PHASE TWO –POST-INTERVENTION STAGE: DATA ANALYSIS, FINDINGS and DISCUSSIONS

6.0 Introduction

This chapter discusses the data analysis, findings and discussions from the final semi-structured teachers' interviews and focus group interviews in December 2015 and January 2016, with the same research study population as in 2012-2013.

This section of the study focused on longitudinal qualitative research, with the same participants over a time period sufficient to allow for the collection of data on areas of interest that may be subject to change. The discussions underscore the principal aim of longitudinal qualitative research; to expose process, evaluate causality, and substantiate micro-macro linkage (Hermanowicz, 2013). To this end, in this study, longitudinal qualitative research, has arisen as an innovative way by which to understand developmental change, over time, whether conceived at an individual, group, institutional, or societal level (Ruspini, 1999). Therefore, the longitudinal study of teachers gave a time perspective on the life and work of teachers, instead of just a snapshot at a particular point. The time period in question, was three years between the first and second semi-structured interviews. This longitudinal research project was useful in exploring the stability of the teachers over time and how they may have changed their practice (Raudenbush and Bryk 2002; Singer and Willett 2003; Hitt et al. 2007).

Taris (2000: pp.1-2) explained that longitudinal "data are collected for the same set of research respondents for two or more occasions, in principle allowing for intra-individual comparison across time". Perhaps more directly relevant for the current discussion of this longitudinal research study related to teaching and learning. Ployhart and Vandenberg (2010) defined longitudinal research as emphasising the study of change and containing at minimum two repeated interviews or observations on at least one of the substantive constructs of interest (in this study the teacher participants). Compared to Taris (2000), Ployhart and Vandenberg's (2010) definition explicitly emphasises change and encourages the collection of waves of repeated measures. Therefore, Ployhart and Vandenberg's definition may not be overly restrictive. Ployhart and Vandenberg's (2010) directly examine change in a criterion as a function of differences between person variables. Otherwise, one must draw inferences based on retrospective accounts of the change in criterion along with the retrospective accounts of the events; further, one may worry that the covariance between the criterion and person variables is due to changes in the criterion that are also changing the person. This design does not eliminate the possibility that changes in criterion may cause differences in events (for example, changes observed in psychological and behavioural variables lead people to decide to leave the school). Furthermore, interviewing the same teachers at intervals over several years has the advantage of enabling me to get to know the participants well. As a result, I was in a better position to understand what the participants were saying in the interviews and assess the veracity of their self-reporting about their views and practices, past and present. Also, a degree of trust was established such that the teachers were more likely to be frank about their feelings, challenges, and concerns. One positive impact on the teachers' experience, for example, helping them fine-tune their practice and maintain their morale to an unusually high level.

Feedback (for example, less use of textbooks; more active engaged lessons; more use of the IT facilities) was given to the Majac Secondary School mathematics department on 26th November 2013 which led to subsequent changes to teachers' classroom pedagogy. As part of Majac Secondary School's observation policy teachers were observed each term and observation notes identified that a range of activities supported student learning, for example, more use of ICT facilities, real-life engagement activities, less use of textbook in the lesson. Therefore, in the feedback I provided to the mathematics department these issues and in subsequent observations I noticed that the teacher classroom practices and approaches changed.

Qualitative longitudinal research is predicated on the investigation and interpretation of change over time and process in social contexts such as in mathematics classrooms. Therefore, semi-structured interviews were conducted with teacher participants after a three-year period and during these interviews, the participants were invited to reflect (thus covering similar events to those incorporated in a retrospective design) or anticipate forward so that events in the period between interviews were also covered in the conversation, as well as being encouraged to think about longer-term pasts and futures (Miller et al., 2014). Due to their resource-intensiveness, qualitative longitudinal studies are relatively niche, yet they represent a relevant qualitative approach as in this research study the data over the three-year period was considered as detailed with unique insights (Finn and Henwood, 2009).

The research reported in the Literature Review (Chapter Two) brings together a focus on effective teaching and learning for students grouped by ability and emphasised Majac Secondary School mathematics department's processes that determined the composition of ability sets and its analyses of the characteristics of students in these sets. For example, the student participants were placed in ability settings since their inception in Year 7 and they could be moved between sets every term based on their progress made in internal assessments. Therefore, it would be unlikely for the teacher participants to have the same students throughout the longitudinal study and could not comment on the progress of these particular students over time.

There was an opportunity lost in not gathering student feedback after the action research cycle interventions. However, a research focus was on the change in students due to the interventions. Internal validity is generally seen as contributing to the soundness of this study's findings (Santacroce et al., 2004), and as such, can be enhanced by careful attention to maintaining the integrity of the research cycle intervention delivery across sessions or between different ability groups (Dumas et al., 2001). Confidence in this research study's findings were increased when strategies for improving internal validity have been incorporated into this study's design.

When an intervention is tested and no difference is found between groups, the first conclusion could be that the intervention was not effective. Other potential explanations include (a) an insufficiently operationalised intervention, (b) insufficient power from small sample sizes or less powerful analytic techniques, (c) too much heterogeneity within each group on the dependent variable, (d) lack of sensitivity of the measurement of the outcome variables, or (e) incorrect timing of the outcome measurements (Lipsey, 1990). If power, heterogeneity, sensitivity, and timing questions can be addressed readily, then the intervention itself needs to be evaluated. Furthermore, Silverman (2010) argues that qualitative research approaches sometimes leave out contextual sensitivities and focus more on meanings and experiences. Phenomenological approach, for instance, attempts to uncover, interpret and understand the participants' experience (Wilson, 2014; Tuohy et al., 2013). Similarly, Cumming (2001) focused on the participants' experience rather than any other imperative issues in the context. Therefore, the student experience and perceptions of the intervention was important, and it helped Ms Hanekom and I to identify, through our engagement and discussions, the best way to improve mathematics while providing equity among all students.

'Groupthink' (Janis 1972) involves a 'bandwagon effect,' where people endorse more extreme ideas in a group than they would express individually. Social desirability pressures induce participants to offer information or play particular roles, either to fulfil the perceived expectations of the facilitator or other participants (Aronson et al., 1990) or to present a favourable image of themselves (Goffman, 1956). Therefore, if specific questions in relation to the interventions would have been asked to the student participants, they would not express their 'real' thoughts during the focus group discussion (Albrecht, Johnson, and Walther 1993; Carey 1995). Furthermore, social influences such as conformity and social desirability; are most troublesome for studies, such as this one, that used focus groups as a way to measure individual attitudes or beliefs.

Wilkinson (1998: p.119) states that, "underlying concerns about 'bias' and 'contamination' is the assumption that the individual is the appropriate unit of analysis, and that her 'real' or 'underlying' views. In this view, individuals possess 'real' beliefs and opinions, and the most important issue for focus groups is simply how to best access these ideas. In contrast, a social constructionist perspective suggests that individuals do not have stable underlying attitudes and opinions; rather, these ideas are constructed through the process of interaction (Potter and Wetherell 1987; Albrecht, Johnson, and Walther 1993; Delli Carpini and Williams 1994). In this view, conformity, groupthink, and social desirability pressures do not obscure the data. Rather, they are the data because they are important elements of everyday interaction. The tension between these two perspectives underlies many of the divergent uses of focus groups in the social sciences (Cunningham-Burley, Kerr, and Pavis 1999; Wilkinson 1998). To this extent I decided not to engage the student participants with the questions that would allow group pressure.

Chapter Four, Table 4.1, shows the research questions and the associated data source. Teacher interviews were face-to-face and took an in-depth form, as the intention was to gain access to teachers 'perceptions of teaching mathematics and how these might change over time. The student focus group interviews were face-to-face and the purpose of conducting them was for me to find the group perceptions of the methods and strategies used by teachers. The next section discusses the Phase Two analysis of the semi-structured teacher interviews and student focus group interviews.

6.1 Analytical Approach of Semi–Structured Teacher Interviews

The semi-structured teacher interviews (in January 2016) were used because they provided a very flexible technique for a small-scale research (Drever, 1995) such as this study. The interviews were undertaken as the teacher participants had expert knowledge that determined their views of factors that facilitate achievement in mathematics and strategies that supported students' learning in mathematics. Appendix I contains the questions (the same questions used in Phase One).

The data analysis followed the same process of inductive analysis as described in Chapter Four section 4.2. where the teacher participants, in the study, were asked questions such as: *when do you think students learn well? What are some of the things you've tried to do to get through to these students?*

Recruiting and retaining sufficient qualified mathematics teachers to serve the students at Majac Secondary School was one of the key challenges for the SLT. The mathematics department 'lost' three teachers, out of a complement of twelve full time and one part time, in April 2015 and Mr Tromp, who moved to another country to work in an independent school, was one of them. The 'loss' of three members of staff in the mathematics team was a significant challenge because the HoD had to find suitable qualified teachers to fill those vacancies. Worth, De Lazzari, and Hillary, (2017) found that the rate of early career teachers in mathematics leaving the profession is particularly high and demonstrated the increase in both turnover and teacher leaving rates over the last few years. The four remaining teachers in the study (Ms Hanekom, Mr Smith, Mrs Van Turha and Ms Adams) remained at the school and as part of the study. Mr Davids, an NQT, who soon found a mentor in Mr Smith, replaced Mr Tromp.

Table 6.1 shows the findings from the questions asked to all the teacher participants. These findings relate to the themes emanating from the questions asked in Phase One and Two to all teacher participants. Each theme was validated by the words of the teacher interviewed, providing a more comprehensive understanding.

I examined the commonalities and differences among the teachers' responses. Additionally, the responses were categorised according to the interview guide of Silverman (2013). The flexibility of the semi-structured interview me to pursue a series of less structured questioning and permitted me to explore spontaneous issues raised by the teachers. Bridges et al., (2008) stated that through the semi-structured interview guide the interviewer devise a ‘spine’ of themes which act as a framework to guide the interview process and reflect the interviewee’s personal experiences of the topic in question.

Table 6. 1 Themes from Teacher Interviews

Teacher Interviews					
THEMES:	**Ms Hanekom**	**Mr Smith**	**Mrs Van Turha**	**Mr Tromp**	**Ms Adams**
1. Motivation to learn	motivate career of the future good GCSEs	challenge mastery students always believe they can	good exam results parents	wants to do well. parents experience real life	engaged settle them down
2. Reaching the most difficult student	be there for students	change the way you teach. real-life applicable difficult / challenging	every child can succeed	know more about the student. think about the student, reach him/her	support and intervention succeed in life.
3.Characteristics of a good educational moment	practical side of the activities encouraging respect engagement	took students aside and showed a small group. struggled	engage dad taught me showed me	friend showed	achieved independence dad showed patience struggled
4. How to motivate students to succeed at school and in the future	open doors best possible results in maths	be consistent. the same treatment	inquiry mind	responsibility own learning	conversations encourage life experiences interests
5. Students' background	relationship role model	disagree turnaround from their circumstances achieve	agree home background	build relationships	help and motivate relationships. parent and student
6. Interest of students	conversations observe and talk to students relationships	conversations I am available		know more about the student. can reach him/her	teacher's love for maths

6.2 Analytical Approach to Student Focus Group Interviews

The final focus group interviews followed the same format as the initial focus group interviews, in Phase One, Chapter Four, section 4.3. In order to further understand the impact of the initial intervention and to establish if the students' progress could be affected by different elements in the classroom, the same interview guide was used as in Phase One, see Appendix E, to inform the questions asked.

6.3 Semi -Structured Teacher Interviews and Student Focus Group Interviews- Findings

The data provided for the teacher semi structured interviews and focus group interviews with students will be related in the form of qualitative self-reported data. The findings of the discussions of the focus groups will be discussed. They will be presented in the form of vignettes, with a summary of all the focus group interviews. This form of group interview, as opposed to individual interviews, was to encourage students to open and talk freely about what they do in their mathematics classrooms. It was reasoned that in this study, the focus group interview would be an appropriate research tool for data collection since young children and adolescents tend to self-disclose spontaneously (Krueger and Casey, 2000) with the ability to tell remarkably consistent 'stories' about life in certain situations (Green and Hart, 1999). The quotes listed in the discussions form just a small part of the larger conversations and observations.

It was clear from the discussions that the role of the teacher was paramount to students' achievement in mathematics as four students stated during the interview:

> **HA** …he taught it in a way … you still learned stuff… it wasn't… over-the-top fun... I would always be very excited … Because it really affects you … having a good teacher, because you're not going to enjoy the subject if you really don't get on with the teacher.
>
> **SA**…our class wasn't the best behaved, but he managed to keep all of us under control… He taught the subject really well.

DA…she… got all of us really interested in the subject without … doing loads …. you'd still learn but it would be fun at the same time.

LO… the teachers actually work really well. They explain it fairly clear.

The students stated clearly that the role of the teachers in the study was very important. The students valued the teachers' subject knowledge (*taught the subject really well*); the teachers' explanations (*explain it fairly clearly*) and the teachers love for the subject (*got all of us really interested*) which supported their learning and led to student motivation in the classroom. The students are representing what other research (Hill, Rowan and Ball, 2005; Baumert et al., 2010; Voss, Kunter and Baumert, 2011) found concerning teacher subject knowledge which influenced academic outcomes. Therefore, the overall finding on the role of the teacher involved them (students) valuing the *subject knowledge of the teacher* to support their learning of mathematics in the classroom.

Students in the high-and middle-ability groups agreed with students in the lower ability groups that the textbook use in lesson needed to be minimised and the lessons needed to be more active. Eight students stated they preferred no or limited use of textbooks:

HA: … should have more interactive... And you don't just sit there and do textbook work… you actually use some software on the computer … different, rather than just do textbook.

LO: I don't enjoy sitting behind a textbook or a desk…

SA: … we had revisions …so it would be kind of sitting doing textbook work.

DA: … a couple of teachers do … practical work. The rest … chuck you a textbook and …you mark your own work …

RA: …So instead of… giving a textbook and just sitting there … makes you … not like the topic already.

GR… they chuck you a textbook and …mark your own work and stuff, and …when you ask for help, they say, just do it.

AL: … quite a lot of them just give us textbook work, they're not actually teaching up on the boards. That's hard to learn if you're learning yourself from the textbook. It's not really good, to be honest.

RO: … So instead of … giving a textbook and just sitting there doing your work, that kind of makes you not like the topic already…. I don't enjoy sitting behind a textbook….

The students felt that considerable parts of teaching and learning mathematics seem to involve mechanical calculations page after page in a textbook. "chuck *you a textbook…*"; "*give us textbook work".* The students expressed frustration over the use of textbooks in their mathematics lessons, which were monotonous and boring. The students could not maintain *the joy to learn* if a task were assigned from a textbook, which was uninteresting and meaningless. Therefore, the main finding was that the students indicated that the use of the textbook does not support their learning because the availability of technology provided the opportunity for teachers to deliver a new and relevant way of teaching and learning (Collins and Halverson, 2009).

During the focus group interview students stated that they preferred hands-on teaching through active engagement/involvement in activities. As stated by six students:

BR: … my teacher showed us how to balance equations

RO: … I probably remember when I learnt how to shoot properly in netball

JU: … I remember when first I learnt how to ride a bike.

AL: …I learnt how to do layups in basketball.

GR: … showed me how to catch a fish.

LO: … teachers …are not active enough … they're there to … teach… but … some of them just stand there and just talk at you. … make you feel as if you don't have your own… opinion … you need to join in with the lessons … they need to make it more active and … easy for you to ...

Four students felt that their teachers tried to focus on engaged learning through activities and therefore the word used the most by students was '*fun*' and stated:

GR: … he's like **fun** … if we're doing a game.

AL: … I found basketball more f**un** to do.

JU: … It was **fun** … because I didn't know how to do it so well.

RO: … you're … having **fun**, however learning at the same time...

Skinner et al (2008) described student engagement as the quality of a student's involvement in school and a student's interactions with classroom activities and materials that produced actual learning thereby shaping their academic retention, achievement, and resilience. Students who were engaged in classroom activities initiate action, exert extensive effort, show positive emotions during the task assigned in addition to being enthusiastic, optimistic and interested in the results of the assignment (Skinner and Belmont, 1993). Henningsen and Stein (1997) suggested that students' ability to complete higher-level mathematics would change when classrooms become environments where students were able to engage in mathematical activities that were rich and worthwhile. The students identified the engagement of the teacher as instrumental in their learning and progress in mathematics and therefore key to establishing a fertile learning environment.

Motivation was among the most powerful determinants of students' success or failure in school (Mitra and Serriere, 2012). Students felt that teachers would enhance their performance in class when they were more motivated. Motivation is defined in different ways in the literature, and I chose to use the following definition: Motivation is a potential to direct behaviour that is built into the system that controls emotion. This potential may be manifested in cognition, emotion and/or behaviour (Hannula et al., 2004). As five teachers stated:

> EMH**:** … I try hard… there are days that I want to give up but…I believe in every child can succeed
> …relationship building is very important. …to be a role model to students and steer them in a direction that I feel they should be attempting
>
> RMS: The challenge of something new and mastery. Accomplishing something new
> ...made it real-life applicable… when you have a … challenging class during period six (end of the day) you … change the way you teach
>
> DMvT: … when they receive good exam results and… a handful of them … can rely on their parents
> … believe every child can succeed
>
> AMD: The students … wants to do well, they want to please their parents… they experience real life in a bigger school
> … think about the student; think how you can reach him/her, so it means you need to know more about the student
>
> SMA: … students need to be engaged... get on immediately as this will settle them down
> …students to succeed in life and with the correct support and intervention….

While motivating students can be a difficult task, the teachers perceive the rewards as being worth the effort.

Motivated students are more excited to learn and participate (Ryan and Deci, 2009). Trying and failing to motivate unmotivated students is a common frustration among teachers. It is a frustration with seemingly no real answers beyond the same old, same old (Dornyei, 2009). According to Education Matters (2008), students' commitment in mathematics refers to students' motivation to learn mathematics, their confidence in their ability to succeed in mathematics and their feelings about mathematics. Students' commitment in mathematics plays a key role in the acquisition of mathematics skills and knowledge (Education Matters, 2008). Furthermore, Sullivan, Tobias, and McDonough (2006) assumed that low motivation of students is the determinant of the apparent lack of engagement. They incorporated Hannula et al's (2004) definition of motivation into their work and stated that "the potential to direct behaviour that is built into the emotion control mechanisms. This potential may be manifested in cognition, emotion and/or behaviour" (Sullivan et al., 2006: p. 82).

The next section discusses how the findings in regard to learning and teaching mathematics emerged as three themes: *the need for motivation, lack of engagement* and *teacher subject knowledge*; through semi-structure teacher interviews and focus group interviews with students.

6.4 Emerging Themes

The semi structured teacher interviews highlighted the importance of providing teachers with the necessary resources and adequate training for working at a comprehensive secondary school. Hence, the importance of good subject knowledge and motivation was also stressed because a student's success depends on the calibre of teacher. Although there does not seem much difference between what teachers see as factors contributing to good achievement in mathematics, there were differences between the teachers' responses about problematic areas. Factors that were lacking at Majac Secondary School included a) interest and love for mathematics, b) respect for the teacher, c) well-behaved students, d) attitude towards subject and e) teacher dedication.

Semi-structured teacher interviews		
Themes	**Phase One**	**Phase Two**
1. Motivation to learn	Motivating students of all abilities	Engagement Attitude Determination

2. Reaching the most difficult student	Teaching methods and learning strategies in behaviour management	Supplementary teaching to support Student behaviour
3. Characteristics of a good educational moment	Personal experience in school Self-worth through reading Supportive environment Realisation of facts	Support within the school Caring Devotion, Creating a positive student experience
4. How to motivate students to succeed at school and in the future	Students' successes and failures in the mathematics classroom	Get to know your student's interests Believe in your students that they can succeed A consistent approach
5. Students' background	Hope and aspirations for their learning Being a role model for students	Poor performance
6. Interest of students	Techniques to support and enhance student achievement	Show the students your love for maths Listen to conversations about students Conversations and discussions

Table 6. 2 Two Phases of Data Collection Analysis

Table 6.2 displays the themes from Phase One and Phase Two which indicates that themes such as, *motivation to learn* and *reaching the most difficult student*, were evident in both phases and as such were the concerns for the teachers in the study. Therefore, Bronfenbrenner (1979) and Jacobs (2020) SEMISM outlined elements such as: person, process, context, and time which, together, could be described as influencing the development of the student. Hence, ways were considered in which to use some of the elements in the mathematics intervention, in the contexts of families and the educational setting, and through interactions between students and teachers. For example, personal characteristics of the teacher influenced developmental outcomes. In any situation, teachers bring with them a range of personal characteristics drawn from their biological as well as their experiential history. They include characteristics of demand, resource and force (Bronfenbrenner 1979). For example, demand characteristics such as temperament, age, gender and moment; may influence not only the ways in which teachers engage in interactions, but also the ways in which students interact with their teachers. In Table 6.2 *Characteristics of a good educational moment;* for example, was supported by teachers *support within the school, caring, devotion, creating a positive student experience.* Furthermore, context was a predominant feature of ecological theory, with its attention to micro, meso, exo and macro levels. The importance of levels (contexts) in ecological theory remains, with micro level identified as primary sites for proximal processes. Despite this, what occurs within one level can influence what occurs within other levels. Experiences from several levels can generate both consistency and tension, for example, experiences within the meso level created when the micro level of school, prior-to-school and home overlap, can be particularly important in supporting students and their families as they manage to engage with mathematics at Majac Secondary School (Dockett and Perry, 2007).

The student participants in the study identified in Table 6.3 key concepts about what they shared as similarities and the different colours indicate the similarities.

Table 6. 3 Key Concepts from Student Participants

STUDENT COHORT
• Low motivation from their teachers
• Limited resources to offset the effect of lack of active engagement in mathematics • Most students prefer hands on / active engagement in lessons
• Some teachers need to be more enthusiastic and engaged in the mathematics lessons • Most students wanted to engage through 'fun' learning
• Some teacher dedication towards their work and students • Teachers' characteristics were one of the important factors that contributed to high achievement
• Students want limited or no use of textbooks in the lesson • Limited or no use of textbooks in classrooms
• Limited access to knowledge of how mathematics relates to future career opportunities • Limited or no use of mathematics in the future
• Interactive learning style encouraged • Limited learning styles to address different mathematics topics
• Some group work with fellow classmates • High expectations of teachers that leads to improved learning

Furthermore, Table 6.3 identifies those broader meanings, interpretations and significances in the form of general themes common to all participants arise (Falmagne, 2006). This was because “the outcome of research cannot merely be a collection of particularised case histories” such as might be presented in discrete themes or discrete participant characteristics (Falmagne, 2006: p.171). Generating themes with an awareness of participant particularities and generalisations, it was found that the meaning expressed by one participant helped me to understand and make sense of what came next from another participant. This justified one of the goals of analysis, which was to “produce meaningful condensations that make it possible to gain from one participant an understanding that can enhance ones understands of another participant as well” (Falmagne, 2006: p.181). Conversely, thematic analysis also involved noticing how one participant’s expressions fitted into a chosen theme, while another might have indicated a divergence from the it.

The themes will first be presented in a figure and then described. It is not always possible to separate themes, so in certain instances a description of one theme will refer to the contents of another theme.

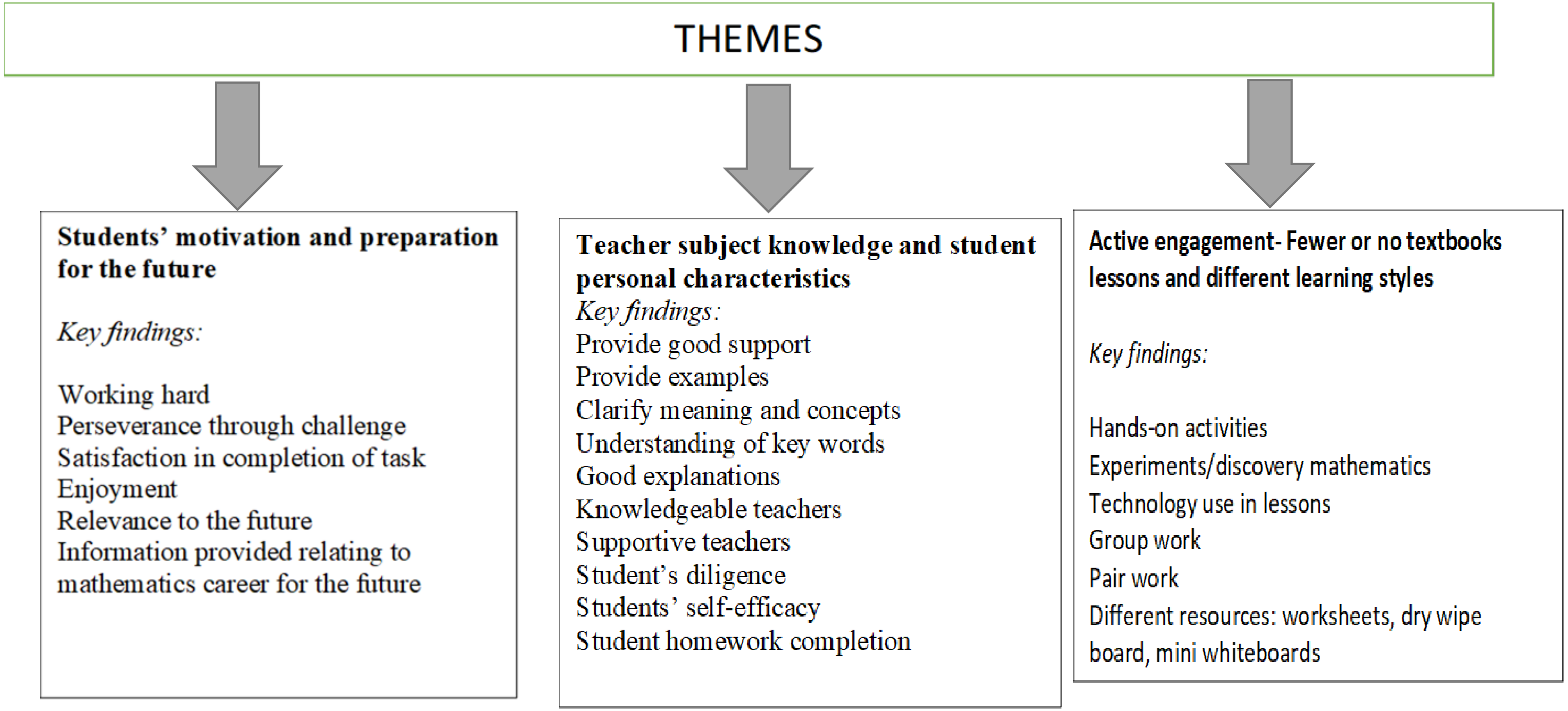


Figure 6. 1 Themes Presented

6.4.1. Theme One: Maintaining Levels of Student Motivation and Preparation for the Future

The student participants, in particular Logan and Dakota, stated that a few of their teachers' lessons were demotivating them, for example, '*you've got a bad start with them*'; '*some of them just stand there and just talk at you'* and '*...chuck you a textbook and then they just mark your own work and stuff ...you ask for help they say, just do it…*'. It also demonstrated the feelings of the students towards their teachers and how they were '*frustrated'* with the norm and would appreciate a change in their curriculum. Viadero (2005) and Anderman (2003) examined the importance of teacher-student relationships, school belonging and motivation. They found that if a student has a good sense of well-being and belonging in school, that the student's motivation will be greater. The DfE (2017: pp.7-8) stated that:

> Cultivating more positive student attitudes in order to improve students' motivation and attendance is key and teachers develop a range of strategies to overcome this (such as dialogic approaches) with varied effectiveness. Motivation is low for many students, although there are some who do see this as an opportunity to improve their attainment level and therefore engage more readily with the lessons. Mathematics generally evokes a stronger reaction (pp.7-8).

Evidence to support its view were found in one of the student's in the study, Roan, words:

RO: …I don't feel as if I'm seen like an individual kind of person… teachers maybe should kind of check-up one you once in a while or like see if you're struggling on anything, just show … more enthusiasm for … what you're doing.
Because if you've done something well, you've put a lot of effort into it, and they don't really … value it, value you for it.

When the student (Roan) raised the concern above, he clearly identified that he was working hard and he showed perseverance, but the teacher was not taking an interest in him and his work. As a 14-year-old student, he was still interested in what the school offered him and therefore he wanted to be led by his teachers and their interest in him as a student and his work. A variety of researchers concur that higher levels of interest, motivation, self-efficacy, and engagement can produce higher levels of achievement (Koller, Baumart and Schnabel, 2004; Schwartz, 2006). The mathematics teachers, in the study, organised the learning experiences of their students and consequently were in a critical position to use their views, conceptions and attitudes to influence the students. However, the students were clear that they *persevere through challenge* and were *satisfied* when they had completed their set tasks, but their teachers' influence of low motivation affected their learning.

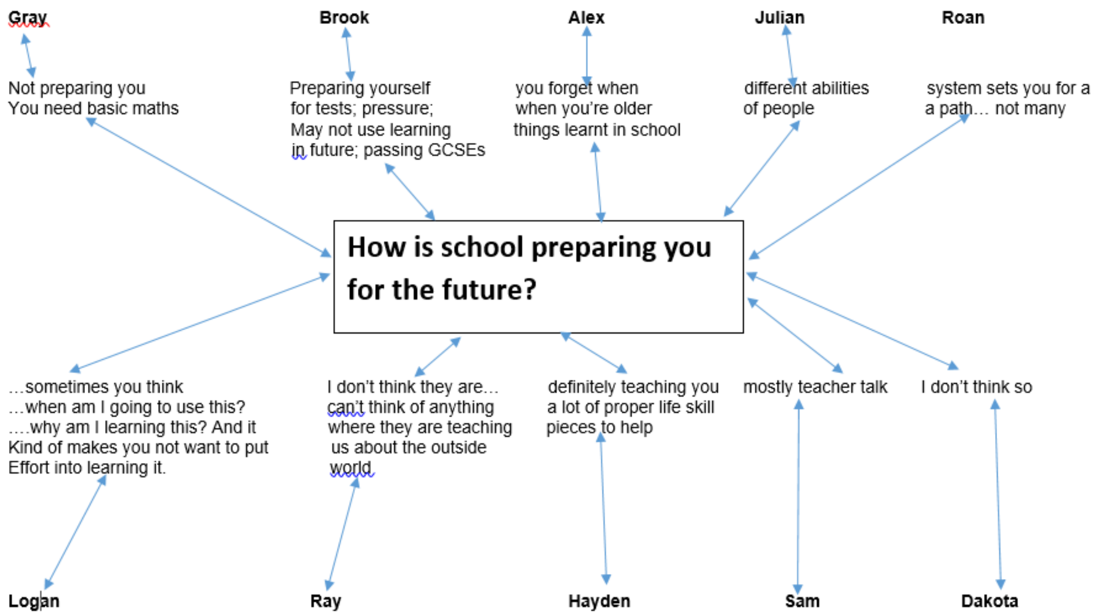


Figure 6. 2 Data Coding of Students' Comments

Figure 6.2 showed that most of the students in the study (n = 9) agreed that school does not prepare them for the future, and more specifically mathematics did not support their needs in the real world. The students stated that too often, the focus of mathematics is *content,* with little connection to why it matters. Instead of learning together, many students spend hours filling in worksheets or working from textbooks. The students mentioned that some of the lessons were *boring* and *irrelevant.* Too often, the lessons they listened to were boring and irrelevant to their lives. In addition, the students identified that most of the content of mathematics was simply memorised, learnt for a *test or an exam* and then *quickly forgotten*. This *pressure* on students to perform cultivated a fear of failure and the students experienced mathematics as a *difficult, challenging* subject.

The student participants (n=9) were expressing themselves in particular ways that reflected certain honest and emotions when they made comments about these issues. Therefore, it was an important theme to discover that the school or mathematics department does not prepare them for their future lives. Jacobs' (2020) SEMISM identifies that the students in the *micro level* needed support from teachers' subject content knowledge and pedagogical knowledge (*exo level*) which would support their achievement in mathematics.

6.4.2 Theme Two: Active Engagement- Fewer or No Textbooks Lessons and Different Learning Styles

Most of the students identified *hands-on, active engagement* as an important approach of instruction to guide them to gain knowledge by experience. Therefore, they would get the opportunity to manipulate the objects they were studying, for instance, calculators, rulers, mathematical set, and shapes. The students knew that they would be the active participants in the classroom as three students, stated:

RO: … you shouldn't just sit there… not doing your work, …you need to… join in with the lessons and stuff, and … they need to make it more active.

… maybe have a few more active lessons … for each lesson maybe have a starter activity which kind of gets you going. So … maybe… a fun activity, but you're still… learning something from it.

LO: … many teachers …are not active enough … they're there to … teach and stuff, but … some of them just stand there and just talk at you. … make you feel as if you don't have your own… opinion, …you need to join in with the lessons … they need to make it more active and like easy for you to … get your voice across.

HA: … maybe they should have more interactive … something that you would actually relate to …you actually use some software on the computer or something different, rather than just do textbook.

Student participants (n = 8) knew that hands-on approaches or active engagement activities would increase their academic achievement and understanding. As stated in the students' comments they would be able to *engage in real-life* illustrations and observe the effects of changes in different variables; for example, in a 3-D shape on the interactive whiteboard. It is obvious therefore, that any teaching strategy that is skilled towards an active engaged direction could be an activity-oriented teaching method (hands-on-approach).

Furthermore, students (n = 8), in this study, acknowledged that teachers are too reliant on the use of textbooks in their lessons. The use of textbooks in mathematics classrooms displaced the teacher's ability to shape in their students an identity of participation. At Majac Secondary School, issues of inclusion and exclusion in learning were revealed. Thus, some students were shaping an identity of non-participation maintained by the practice of relying on textbooks to teach mathematics. Most of the students (n=8) commented that they were expected to work individually to reproduce what the teacher and textbook had shown them (Romberg and Kaput, 1997). Four of the students stated:

> **HA**… you don't just sit there and do textbook work…, you actually use some software on the computer or something different, rather than just do textbook.
>
> **LO**… just give us textbook work, they're not actually teaching up on the boards. That's hard to learn if you're learning yourself from the textbook.
>
> **SA**: …so it would be kind of sitting doing textbook work …
>
> **DA**: …and only a couple of teachers do … practical work. The rest is like chuck you a textbook and then they just … mark your own work and stuff, and then even when you ask for help, they say, just do it.

The widespread use of textbooks raises concerns about the learning activities in the classroom which students were expected to engage in. Shield (2000: pp.516-521), explains, "… textbooks do not convey the intent of recent reports and syllabi, even though they were written in response to these documents". He suggests that whilst it is not possible to replicate everything in syllabus documents, it "should be possible to develop textbook presentations which come much closer than at present". Teachers should create opportunities for students in the classroom where they (the students) can shape what they can do, who they are and how they understand what they do. Providing resources for learning as well as contexts for manifesting learning through participation, are necessary as the students had concerns with learning mathematics from textbooks.

6.4.3 Theme Three: Lack of Teacher Subject Knowledge and Student Personal Characteristics

Most students considered teacher characteristics such as patience, being exciting, reliable, caring, honest, encouraging, as a mechanism that would support their mathematics achievement. Three students stated:

RA: … he was very energetic about the way he taught, so that helped … quite a lot, because you didn't feel as much … just learning.

LO: … he's very good, because he actually talks to the class a lot.

AL: … very patient. … and they …understood how I was quite slow learning…

Rockoff (2004), Rivkin, Hanushek and Kain (2005) and Aaronson, Barrow and Sander (2007) stated that teachers have a direct responsibility to shape a student's academic achievement and were the most important school-based factor in their education. Therefore, the students, in the study, identified the positive characteristics of the teachers that supported their learning. Three students mentioned:

LO: …they explain it fairly clearly.

HA: … he taught it in a way where it wasn't boring but … I would always be very excited...

SA: … he managed to keep all of us under control … He taught the subject really well. … that was good".

Students demonstrated that they needed SCK through their development of their own understanding of mathematics and their learning about the connections between topics and, in their comments that they saw this as distinct from their Common Content Knowledge (CCK) learning gains. Three students stated:

BR: … we don't even know what … our new topic is… We hadn't gone over … everything that's actually in the test, and it's hard to … move on to something new when you don't really understand the topic before.

RO: ... we've missed out one of the topics. And she was …, you're just going to have to revise it. But how are we supposed to revise it when our teacher hasn't even taught it to us? ….

…They kind of just give you that and say … tick it if you get it. And I just don't... I don't feel … it works. …you don't really get into that new topic.

GR: …the questions you got wrong it says, do question 19 and 18, right? It's not going to help you because you got them wrong, so how are you going to get them right on the textbook, because it's exactly the same as the test.

The students identified, having gone through the lessons of the teachers, that they would welcome opportunities in lessons for more: collaborative work, peer and teacher support, experiencing a range of learning styles and levels of engagement with teachers on topics of concern and how they could improve to support their progress. Subject knowledge has a very important role to play. High-quality teaching rests on teachers understanding the subjects they are teaching, knowing the structure and sequencing of concepts, developing factual knowledge essential to each subject and guiding their students into the different ways of knowing that subjects provide: subjects create disciplined ways of knowing. Consequently, the students in the study stated that their teachers' level of subject knowledge influenced their academic achievement. Three students stated:

HA: … asking them questions and you feel comfortable around and makes that subject a good subject …they're making it good because they're teaching you well

DA: … are really good and I'm excited to learn …

HA: … it's good to have a good teacher because if you don't have a good teacher and you don't enjoy being taught by that teacher, it really affects your lesson.

Moreover, the students were motivated by their teachers whose love for the subject was so thrilling that it inspired the students to pursue the subject themselves when they move to college, university, and the world of work. Three students stated:

JU: …an experiment or practical. So, it's … better to have practical, because it's more fun, and like you see it for yourself…

BR: …when your teacher like lets you make a slide show or something. So, it kind of shows what you've learnt from that…

AL: …something physical. And if you do something physical, I think you learn it a bit better …

The students engaged through active, hands-on activities planned by the motivation of the teacher for them to succeed and for student achievement to develop.

The students, in the study, knew that the teachers should demonstrate:

- a secure knowledge of the subject and curriculum area, foster and maintain students' interest in the subject and address misunderstandings;
- a critical understanding of developments in the subject and curriculum areas, and promote the value of the subject at, for examples, open evenings;
- an understanding of and take responsibility for, promoting high standards of literacy, numeracy, articulacy and the correct use of standard English, whatever the teacher's first language is; and,
- a clear understanding of appropriate teaching strategies.

Therefore, the schools' plan was to provide the students with qualified mathematics specialist teachers with good subject knowledge but due to recruitment and retention, at times a non-specialist mathematics teacher taught them. Ms Hanekom was a non-specialist mathematics teacher, but her qualifications did not stop her from being a teacher who strived to support, encourage, care for, inspire and engage her classes and lessons. Hattie (2011) discussed the importance of subject knowledge and stated that expert teachers can make use of subject knowledge to organise and use content knowledge more effectively for their students to understand. In addition, he stated that expert teachers are more likely to be able to respond to the needs of any particular classroom, recognising students who are struggling and changing the way the information is presented in order to make it more understandable. Hence, two students in the study stated that their teachers' expertise were of utmost important to them:

RO: … I had the chance to be able to correct my technique… and she would let me

BR: … he was just like showing us a slide show on how to do it, and it didn't make … any sense. And then he'd … come round explaining it and showing us different ways how to work it out.

The students' feedback to their teachers indicated that they needed to deploy skills related to the feedback, teacher subject knowledge, and their relationship with the students to complete the process successfully. Therefore, the teachers required a mix of different skills and knowledge that they were capable of weaving together. Hence, the teachers at Majac Secondary School, whether a mathematics subject specialist or a generalist, needed a wide range of different skills and attitudes if they were to assist their students with achieving high outcomes. These could include relationships with the students, subject matter knowledge and an understanding of pedagogical processes to develop the understanding that was required. The next section concludes the chapter.

6.5 Socio-Mathematical Norms

This section explores the three norms that emerged from all data collection episodes in this action research including the observations and findings from the first intervention (see Chapter 5). The three norms are important because they underpin the design of the second intervention held in Riverview Centre, Southeast of England. The norms, *computational strategies, coherency, and justification* will be substantiated by data in this chapter and will be further delineated in the following chapter where their impact on the intervention design and delivery will be presented.

Data for identifying norms came from semi-structured interviews with teachers and focus groups with students during December 2015-2016 school year. This is the time period when most norms have already been established and relatively stable (Wood, Cobb, and Yackel, 1991; Wood, 1999; McClain and Cobb, 2001). Also interview data, from teachers and students, evidenced norms based on unelicited student actions. These are student actions, either discursive (for example, speaking) or physical (for example, writing something on the board), made during whole-class mathematical discussions, that were not specifically elicited by the teacher in their classroom. The rationale for this was to identify behavioural regularities demonstrated by "almost everybody" (Sfard, 2007: p.539), student participants. Since the students comprise almost everybody in the study, the behavioural regularities they collectively demonstrate are the actual norms. I focused only on unelicited student actions that evidenced noteworthy norms. By "noteworthy," I mean norms that are unusual or uncommon in the context of the general U.K. educational system. Students may regularly raise their hands without being specifically prompted by the teacher, but this norm is found in nearly every classroom in the country. As was also discussed in Chapter 5, I interviewed the teachers and students throughout the 2013–2014 school year to provide a means of triangulating my findings in Phase One, thus increasing the validity of them. On each of the interview occasions, with teachers and students, in 2013 and 2015 the same questions were asked, and these questions offered a unique glimpse into what ideas, skills and expectations the teachers and students perceived to be important for the students learning. Hence, these two occasions functioned as a member check for the participants (teachers and students). Participants did not actually use words like *coherency, justification, or active engagement*, but rather used age-appropriate equivalent terms such as 'making connections', 'explain your thinking', and 'following along'. These two occasions, provided a member check of both the teacher and the students, allowing me insight into their perceptions of learning.

In the next section, I will introduce and explain the three norms that I identified from the teacher semi-structured interviews and student focus group interviews in Phase One: *computational strategies, coherency, and justification.* Finally, I will discuss how these norms supported the mathematical tasks/activities at the camp.

Computational strategies

Computational strategies were another socio-mathematical norm evident through the discussions with participants (teachers and students). This norm does not mean that participants shared what computations they did or why they did them, but rather specifically how they did them. Evidence from interviews, stated below, demonstrate these phenomena:

<u>SMA</u>: … do *new methods in a lesson* and I'll say you *choose the method* you would like to choose…

<u>EMH</u>: … a *structured lesson* but also having a lesson that provides *variety, so group tasks, functional activities, mass game*s all keeps them enthusiastic…

DMvT: … *get them to think* about... certainly with Key Stage 4 like with my Year 10s I'm trying to get them to *think about*, you know, *the process they're going to go through...*

Participants may have been utilising these strategies more frequently on their own, but computational strategies focus only on when they shared their computational strategies in whole-class discussions. Therefore, more of the computational strategies will be employed for the mathematics camp.

Coherency/Consistency

Students create mathematical coherency by identifying structural similarities and relationships across and within different mathematics problems, situations, topics, operations, computations, notations, and visual representations. This is evidenced through the following sub-norms:

- Generalising after observing patterns across multiple cases;
- Identifying equivalencies across different notations, operations, units, and visual representations;
- Transferring knowledge from a different problem

Coherency was one of the four socio-mathematical norms that I identified in the teacher semi-structured and the focus groups interviews. As its description above implies, students must have a certain amount of mathematical content knowledge in order to participate in this norm. Hence, coherency is a socio-mathematical norm and not a social norm. In fact, coherency may be summarised by saying that students recognise structural relationships between different mathematical objects. I use 'objects' in a broad sense here, including such things as mathematical problems, topics, operations, notations, numbers, specific cases, properties, and visual representations. Coherency is evidenced through the sub-norm of *student-voiced mathematical generalising,* which will now be discussed.

Student-voiced mathematical generalising; where students are engaged in tasks that allowed for investigation of a phenomenon across many specific cases, was evenly distributed across the six intervention lessons in Phase One. For example, in intervention lesson three; collect and analyse numerical data, the focus was on *addressing perseverance and 'in-the-moment struggles', clarifying the meanings of the key terms to support the students' statistical concepts*. The students were discussing the table shown below in Figure 7.1.

Name	*Age*	*Height*	*Favourite Colour*				

Figure 6. 3 Individual Student Data Collection Sheet

The teachers in the study used the term 'connections' rather than 'coherency' as they believed the students were creating mathematical coherency by recognising similarities and relationships between different mathematical objects. For example, in-class mathematical discussions lend overall support for coherency and Figure 6.3 further supports the connections between the data and the engagement from students with it.

Justification

Students stated in the focus groups that they justify their answers, either verbally or on the board in front of the class. This is evidenced through the following sub-norms:

- Justifying by providing logical steps as well as a basis for those steps
- Justifying through mathematical coherency
- Justifying through visual representations

Justification was one of the norms that I identified in the Phase One intervention through the six intervention lessons. Like coherency, justification is a socio-mathematical norm. To participate in this norm, students must have a certain amount of mathematical content knowledge. To be coded as a justification, a student's explanation had to be associated with a recognisable mathematical claim, either specific or general. It also had to fall within what Harel and Sowder (1998) call the analytical level, meaning that the justification appeals to a basis. The justification sub-norm of providing computational steps was evidenced in intervention six, Basic Algebra; where students used their class notes and exercises to support their learning through writing algebraic expressions. For a contextualised problem, this basis was typically the problem context itself. The following exemplar showcases this: Ray, Hayden and Dakota were in the same group, during intervention six, Ray and Hayden did all the working and explaining through their logical thinking by writing on the mini whiteboard and Dakota just watched. Ray and Hayden's justification consists of primarily listing computational steps. However, Ray and Hayden's use of the mini whiteboard provides the basis for their computations. They both explicitly showed what those computations are accomplishing within the problem context (see Chapter Five, page 236). The justification sub-norm focuses on why students are providing computations (to justify a claim) while computational strategies focus on how students are performing the computations themselves (for example, what strategies they are employing to solve the problem). Thus, considering the student involvement in intervention lesson six, it is reasonable to conclude that justification was upheld in this lesson.

As explained in Chapter 2, each of these three norms has been recognised to be of great importance to learning mathematics. Since these three norms are fairly abstract, the goal of Phase One was to identify more specific, concrete norms that are associated with these definitional norms. I now consider the norms identified in light of the three definitional norms of mathematically productive discussions. The norm of *coherency* was evident from the teachers' and students' comments in the interviews, for example, identifying equivalencies across different notations, operations, units, and visual representations when *teacher participants* stated:

> <u>SMA:</u> … an ability that you need to practice, and that everything that we're doing in maths is developing … *systematic method of problem solving*

> <u>JMM:</u> … *problem solving and puzzle solving* and developing their analytical skills, and … do stuff on *decimals, …examples using money* because they can see *how that relates to them whereas if you just want to add up decimals,* they don't really see the connection with real life

student participants stated:

> **DA**: … lessons …*sometimes outside of the class … measuring stuff* …to make it funner …

> **HA**: …*making lots of posters and stuff* ...

Holding mathematics as the authority means that students appeal to mathematical reasoning rather than non-mathematical reasons (such as the teacher, textbook, social status). Mathematical reasoning appealed to the norm of justification.

Every time students *justified* their claims, for example, through *visual representations*, they implicitly supported the idea that mathematical reasoning was the authority. Three students stated:

> **AL**: …showed us lots of videos, so you learn it more.
>
> **GR**: … getting the children up at the front doing it or going down to the library or using the computers is much more effective.
>
> **RO:** … make a game where you have to get even numbers to move up and if you get …an odd number you move back down

The three socio-mathematical norms (*computational strategies; coherency and justification)* allowed for problem based mathematical activities to be developed for delivery at the mathematics camp.

6.6 Conclusion

Themes that emerged from the data, along with the key concepts, have all been discussed with supporting quotations from the semi structured teacher interviews and focus group interviews with the students. It can be noticed from the quotes that there was a predominance of quotations where key concepts, such as, *motivation*, *active engagement, and preparation for the future*, were discussed with the student participants. The participants expressed themselves in meaningful ways in these key concepts.

It was found that to tease out the key concepts from each other, was difficult because one facet of a participant's quotes tended to be part of another situation in the classroom. Some of these quotes more than once to indicate this complexity. It was noticed how certain features of each participant repeated themselves throughout the themes. For instance, across various themes, the students talked about the teacher's personal characteristics of, *enthusiasm, energy, engagement, care*, which supported their learning. Nevertheless, the students refer to the *low level of motivation* which linked to teacher characteristics, such as '*how to keep the class under control', 'you don't enjoy being taught by that teacher, it really affects your lesson', '…they're not as energetic…you not excited to learn with them'.* Furthermore, each participant's narrative reflected in distinct ways the social context against which he/she experienced and spoke about their classes in the study. In generating themes, trends of expressions and emotions similar to all participants were observed, that is, 'successes' and 'failures' that can be identified and analysed without discarding the particular circumstances or unique social context (classroom) of each participant (Falmagne, 2006). Interpreting the thematic data took place while compiling different themes. In this way, a simultaneous process of analysis and interpretation has begun.

Although both teachers and students from Majac Secondary School discussed different factors that led to good achievement, there were specific findings that were common to both students and teachers:

- Active engaging lessons where students engage with the material, participate in the class and collaborate with each other with support and guidance from the teacher;
- Managing a classroom of students (disciplining students, assigning and collecting homework, assessing and evaluating students and addressing the needs of individuals students) were major challenges for teachers in the study;
- Student interest in mathematics enhances learning, which leads to better performance, achievement and success in the classroom (Hidi,1990);

- Dialogue/conversation was an essential element in the effective teaching and learning of mathematics as it enabled students to think out the ideas contained in the activities they undertook, placing those activities in context. The teachers adopted a variety of questioning techniques, addressing questions to reinforce and consolidate what has been learnt;
- Teachers knew that students walked into their classrooms with a wide range of abilities and tried to find ways to meet the needs of all students, including those with learning and attention issues therefore offering support to struggling students in the study; and,
- The impact of teacher characteristics was important as it ensured that teachers best suited were most able to enhance student performance in the classroom.

There were also differences identified by students and teachers that influenced mathematics teaching.

The teachers' findings when analysed identified:

- Parental involvement in school activities have a positive impact on academic performance – micro, meso and exo levels (Jacobs, 2020, SEMISM);
- Teacher experiences and perceptions about mathematics were important when focusing on pedagogy – exo and meso levels (Jacobs, 2020, SEMISM);
- Students needed to respond proactively and positively to challenge in the classroom and become learners who were in control of their own education – meso and micro levels (Jacobs, 2020, SEMISM).

The students' findings when analysed identified:

- The limited / reduced use of textbooks in classroom - meso level (Jacobs, 2020, SEMISM);
- Teachers' learning styles affected their performance in the classroom - meso level (Jacobs, 2020, SEMISM);
- Mathematics taught in the classroom is unrelated to their future careers - macro level (Jacobs, 2020, SEMISM).

Polanyi (1966) stated that tacit knowledge is unarticulated, 'yet unspoken', tied to the senses in movement skills and accumulated physical experiences. It 'indwells' and is rooted in local action, procedures, routines, commitment, ideals, values, and emotions. In education, tacit knowledge plays a dominant role in the formation of teachers' and students' knowledge systems, world values and value concepts. It is embodied both in personal action and in collective social knowledge, and clearly difficult to make fully explicit and propositional. Nevertheless, it is knowledge that enables teachers and students to move around in the world and is learned principally by participating in a social context, interacting with other people. Students are often able to perform a task successfully without being able to describe how or what they did to succeed (Siegler and Stern, 1998). Therefore, the students in this study identified throughout the focus group interviews that their teachers' personal characteristics, motivation and self-efficacy support their learning journey in succeeding in GCSE mathematics.

Furthermore, for both teacher and student interview data, I focused specifically on teacher actions that seemed to promote the social norms. It is important to emphasise that my goal in Phase Two was not to identify every strategy employed by teachers but rather, I sought to identify strategies intended to support social norms. Therefore, socio-mathematical norms are a subset of social norms that necessarily invoke specific mathematical content knowledge. Norms are identified from observing regularities in group behaviour, for example, through the focus group interviews and Six Intervention lessons in Phase One. Determining 'regular' group behaviour requires many observations of the same group over time. This makes an in-depth, longitudinal study of 10 students an appropriate choice. However, to identify norms associated with mathematically productive discussions for the wider study, it requires a different approach where mathematically productive discussions can be effectively employed and addressed.

Therefore, focusing on student actions ensures that I am focusing on the regularities exhibited by all 10 student participants in the study. As stated, above, these norms supported the intervention for Chapter Seven.

CHAPTER SEVEN: PHASE TWO - THE MATHEMATICS CAMP INTERVENTION

7.0 Introduction.

This section sets forth a way of interpreting a mathematics intervention that aims to account for how students develop their mathematical engagement, attitude and motivation. To do so, I advance the notion of socio-mathematical norms, that is, normative aspects of mathematical discussions that are specific to students' mathematical activity. The clarification of socio-mathematical norms extends from Chapter Six where the semi-structured teacher interviews and the focus group interviews with students identified social norms that sustain inquiry-based discussion and argumentation.

Teaching activities with the 10 student participants where mathematics instruction generally followed an inquiry tradition are used to clarify the processes by which socio-mathematical norms are interactively constituted and to illustrate how these norms regulate mathematical discussions and influence learning opportunities for both the students and the teacher. In doing so, I clarify how students develop a mathematical disposition and account for students' development of increasing their motivation, engagement and attitude in mathematics.

The socio-mathematical norms are intrinsic aspects of the mathematical camp microculture. Nevertheless, although they are specific to mathematics, they cut across areas of mathematical content by dealing with mathematical qualities of solutions, such as their similarities and differences, sophistication, and efficiency (Levenson, Tirosh and Tsamir, 2009). Additionally, they encompass ways of judging what counts as an acceptable mathematical explanation.

Therefore, through analysis of data collection methods responses from students and teachers, Ms Hanekom and I examined how the experiences of participation in GCSE mathematics classes during a summer camp environment influenced students' engagement, attitudes and motivation in mathematics. The next section provides the rationale and design for the mathematical camp intervention.

7.1 Design

In this study, I used the one-group post-test-only design (also known as, one-shot case study) which is a type of quasi-experiment in which the outcome of interest is measured only once after exposing a non-random group of participants to a certain intervention. This quasi-experiment was used to detect the real effects of the camp intervention with ten students in the study. Additionally, the group were known to me, and I had been working with the students over five-years. I had gathered significant experiential data of their approaches to mathematics. Furthermore, the study is an action research project whereby I am refining the intervention based on the outcomes from Phase One. For example, I observed what happened in the previous interventions in relation to teaching and the curriculum, including teacher's subject knowledge, student learning and classroom management which all occurred within a school setting. Therefore, a mathematics camp, away from Majac Secondary School, might increase students' achievement, self-efficacy and also social comfort (the informal learning environment, new activities, small teaching ratio and independence) (Tichenor and Plavchan, 2010; Bhattacharya, Mead, and Nathaniel, 2011).

7.1.1 A model to represent the identified norms

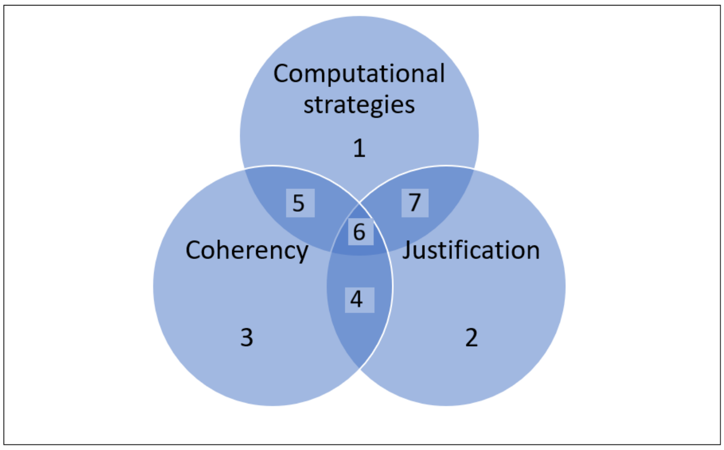


Figure 7. 1 A Visual Representation of the Three Norms Identified from Phase One

I put forth the model, Figure 7.1, as a way to visually represent the norms and the relationships between them. The box in this figure represents a typical mathematics classroom at Majac Secondary School. Inside are all of the noteworthy norms present when the students do mathematics. The triple Venn diagram represents the important socio-mathematical norms and the often-interconnected relationships between them. For explanatory purposes only, the regions within the Venn diagram are numbered. Some student actions only supported one of the socio-mathematical norms (Regions 1, 2, and 3), while other actions supported multiple socio-mathematical norms simultaneously (Regions 4, 5, 6, and 7).

However, norms cannot be investigated in an abstract manner devoid of context. They are inherently tied to the community in which they arose. For this reason, a small group teaching research design is an appropriate choice for Phase Two intervention. Small group teaching is a rather broad term without a clear definition. It covers tutorials, seminars and small problem-solving classes. A small group is a number of people who interact in a face-to-face situation, where the size of the group may vary from a handful of students to around 30 participants. About 8-12 is an optimal number (Walton, 1997; Davis, 1999).

Small group teaching helps in generating a free communication between the group leader(s) and the members and among all the participants themselves. The teachers who act as the group leader(s) are facilitators, who allows the participants to express themselves (Davis, 1999). In fact, a small group setting provides an ideal opportunity for the teachers to facilitate an active student participation (Walton, 1997). The problem-based learning relies almost entirely on the small group teaching methods, and many schools with more traditional curricula have incorporated a significant number of small group teaching sessions in their curriculum (Shatzer, 1998). In this research study, the larger issues of interest are norms associated with productive discussions and teacher strategies used to establish them. So, in Phase Two, this means that I will study a particular group of students in order to contribute to a larger body of knowledge about norms and how teachers develop them.

7.1.1 Participants

The mathematics camp, designed in collaboration with mathematics teachers at Majac Secondary School, took place in the south of England at Riverview (*pseudonym*) activity centre on 11-13 March 2016. Students were able to register for the camp through a written consent form several months before the start of the camp. The camp consisted of all ten students who were participating in the study and who were in Year 11 (undertaking the GCSE examinations).

Three groups of students were selected based on the ability setting of each student in their mathematics class at Majac Secondary School. The groups were: A) Logan, Gray and Roan; (B) Hayden, Alex and Julian *and* (C) Brook, Dakota, Ray and Sam.

Ms Hanekom and I, were the tutors for the weekend away with the students. We were responsible for teaching the intervention sessions. Preparation for the camp can be divided into two parts: planning, organising and administering the camp- and planning the activities to be undertaken at the camp. It was the commitment of all the Year 11 teachers, at Majac Secondary School, who were enthusiastic about the idea of the camp who decided, based on the mathematics department's internal tracking system, which topics should be covered at the camp as intervention sessions.

7.1.2 Riverview Centre

The camp was two and a half days long and students spent each day engaged in a variety of mathematics and Riverview centre led activities. On the first day of the camp, students filled out activity preference sheets and the Riverview instructors matched students to their preferred team building, cooperative interactive activities for the two and a half days. Students participated in at least two of the Riverview centre-based activities over the course of the camp. I was unable to get information from the Riverview centre regarding the activities therefore, there were no opportunity to add the required information to the mathematical intervention activities. I could not incorporate any of these activities into the mathematics-based activities designed for the interventions at the camp. Furthermore, due to the pressures of the GCSE teaching in classrooms and the upcoming examination which Majac Secondary School mathematics department focussed on improving results and schools league tables.

An essential ingredient of the camp was to provide opportunities for a small group of students to make choices regarding the activities they engaged in (Conner et al., 2014). In Table 7.1 the options allowed the groups to discuss a variety of tasks before making any commitments to the tasks, to have a sense of ownership and to take pride and satisfaction in successfully completing their chosen tasks.

7.1.3 Data Collection

The questionnaire administrated after the camp included 10 Likert-type question items addressing the students' attitudes and achievement towards mathematics (1= strongly disagree … 5= strongly agree) was used to understand their perceptions of the camp and how the activities engaged them. The categories on the questionnaire included awareness, perceived ability, value, achievement, commitment and intervention.

7.1.4 Procedure

During this study, I used Phased One pre-intervention session and six intervention lessons to gather data to inform the design of the mathematical experiences for the mathematics camp. The study did not use a pre-questionnaire, and I used the data (two focus group interviews with students, two semi-structured interviews with teachers, lesson observations) to inform planning for the Phase Two camp intervention.

All participating teachers, in preparation for the camp, had previously received training on implementing PBL activities during the camp. The PBL lesson plans were analysed, by the HoD at Majac Secondary School, before the start of the camp to ensure the objectives aligned with the content that was tested at the end of the camp.

7.2 Camp Schedule

On the first day of the camp, students filled out preference sheets and Riverview instructors matched students to two out of three possible outdoor learning activities. The camp mathematics activities span over two-and-a-half days with the sessions dedicated to a range of PBL activities lasting 1hour and 45 minutes and at the same time a Riverview centre activity for 1hour and 45minutes. The mathematics sessions at the camp were held in a conference room as PBL activities required group work and space. **Appendix M** shows a schedule of the sessions and the activities over the weekend and Table 7.1 explained the six activities allocated to the students.

Table 7. 1 Six Mathematics Activities

Set A 5 Short questions = Set 1 Planned lesson NUMBER 1 (Fractions, decimals and percentages) Planned lesson HANDLING DATA 1 (Stem and leaf diagrams) GCSE Problem 1 Functional question 1 5 short questions = Set 2	**Set B** 5 Short questions = Set 3 Planned lesson ALGEBRA 1 (Simplifying, expanding brackets, factorising and solving) Planned lesson SHAPE AND SPACE 1 (Angles, area and Pythagoras) GCSE Problem 2 Functional question 2 5 short questions = Set 4	**Set C** 5 Short questions = Set 5 Planned lesson NUMBER 2 (Estimating and calculating) Planned lesson HANDLING DATA 2 (Pie charts) GCSE Problem 3 Functional question 3 5 short questions = Set 6
Set D 5 Short questions = Set 7 Planned lesson ALGEBRA 2 (Graphs) Planned lesson SHAPE AND SPACE 2 (Transformations) GCSE Problem 4 Functional question 4 5 short questions = Set 8	**Set E** 5 Short questions = Set 9 Planned lesson NUMBER 3 (Ratio and foreign exchange) Planned lesson SHAPE AND SPACE 3 (Construction, angles, area and volume) Problem 5 Functional question 5 5 short questions = Set 10	**Set F** 5 Short questions = Set 11 Planned lesson ALGEBRA 3 (Trial and improvement) Planned lesson HANDLING DATA 3 (Two way tables, questionnaires and scatter graphs) Problem 6 Functional question 6 5 short questions = Set 12

7.3 Data Collection at the Mathematics Camp

As in Phase One, all observations of the students occurred during the mathematics activities since my research goals were to identify norms and strategies associated with mathematical discussions as part of wider remit of the study. Additionally, different discussions and conversations with students were recorded in our own notes which provided insight into the intentions underlying teacher actions, thereby illuminating more subtle teacher strategies.

7.3.1 Data Analysis

The process of analysing Phase Two data displayed many similarities to the Phase One analysis process. For the observational data, I focused specifically on student actions that seemed to promote the productive norms. It is important to emphasise that my goal in Phase Two was not to exhaustively identify every teaching strategy, for example:

- Hands-on ...
- Use visuals and images ...
- Find opportunities to differentiate learning ...
- Ask students to explain their ideas ...
- Incorporate storytelling to make connections to real-world scenarios ...
- Show and tell new concepts ...

employed by Ms Hanekom and me but rather, to identify strategies intended to support the productive norms.

After coding the observational data, the next step in data analysis was clarifying details such as the following: *Under what conditions was the strategy used*? W*ere some strategies more abstract while others were more concrete*? One possible indicator of this is the quantity of teacher actions supporting each strategy. A large number of supporting students' actions could mean that the strategy is favoured by certain students, but it could also mean that the strategy is too abstract and needs decomposing. Likewise, a strategy with a small number of supporting actions could indicate infrequent use. However, it could also mean that the strategy is too concrete and needs to be abstracted and merged with others (Schworm and Renkl, 2006; Ainsworth and Burcham, 2007), as explained in Chapter Two, Section 2.4.5.

It was discovered that teachers used a combination of strategies with a more direct, immediate effect (micro strategies) as well as broader strategies that focused on the students' long-term development and exerted a more indirect effect (macro strategies). From the teacher semi-structured interviews: direct prompts and modelling were identified as strategies for effective teaching. The relative frequency of these micro strategies varied depending on the particular norm in question. The teacher participants also used macro strategies to support development of the socio-mathematical norms, for example, creating a conducive classroom environment, teaching students' mathematical skills, and employing a concept-oriented task philosophy. These macro strategies synergistically supported each other and helped encourage development of the socio-mathematical norms by removing barriers to the norms' emergence, equipping students with necessary skills to participate in the norms, and providing opportunities for the norms to be practiced.

Identifying trends in students using the strategies to solve PBL activities during the 1hour and 45 minutes indicated that the norms (*justification, computational strategies and coherency*) were established.

7.4 Implementing Interventions

The activities for the intervention were a model process, which allowed the teachers to determine the necessary support (Brown-Chidsey and Steege, 2010) to supplement the core curriculum, (Fuchs and Fuchs, 2008). According to Danielson (2007), a key component to the success of any intervention is matching the student with the appropriate support.

The intervention process included the recommendations of structured intervention support to address skill deficiencies that may prevent students from learning the core content. Therefore, the process included activities that supported hands-on, engaged, group work, co-operative learning, team effort and discussions. According to Ravitz, Bekker and Wong (2000) teachers need a paradigm shift from instruction where practices have consisted of teaching all students the same content, with the same delivery and evaluation procedures. Twenty first century learning must move towards creating critical thinkers, who are highly engaged and responsible for their own learning, which must be based on their current knowledge base. However, Buffum, Matto and Weber (2010) states that an intervention should not be a programme developed to simply raise student test scores. Therefore, I was interested in developing students understanding and learning of mathematics *and* to prevent any discouragement due to the belief that it cannot be achieved. Therefore, Stigler and Hiebert's, (2009) recommendation was that teachers need to provide students with learning opportunities to succeed and they need to get students more involved in the lesson by providing them with activities that encouraged student engagement.

At the camp students were involved in the mathematics intervention sessions on a rotational basis. Each group had two sessions: one mathematics intervention and one activity with Riverview centre per day. Students from both the first and second sessions provided verbal feedback which Ms Hanekom and I noted down. Both camp sessions (outdoor learning and intervention) offered the same Problem Based Learning (PBL) activities; however, there were a few PBL activities in the second session that were taught by different instructors due to various reasons (one of the instructors had to leave as his wife went into labour and the other instructor felt ill) but all instructors from Riverview centre received the same training. Therefore, when someone had to leave, they were replaced by a different colleague. Next, I will discuss the identified norms in light of the mathematical intervention activities.

7.5 Identified Norms in light of the Mathematical Intervention Activities

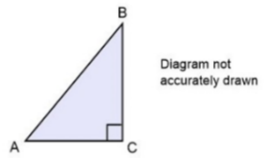
Activities in Table 7.2 included functional mathematics to support student *problem-solving*, *motivation* and *confidence* through the three socio-mathematical norms (computational strategies, coherency and justification), identified earlier. To establish these norms, I discuss in detail one of the tasks from Table 7.2., below:

Starter: Five short questions Set 3:

The students were asked to spend 10 minutes as a small group on the starter activity, which was a mixture of previous knowledge learnt in GCSE mathematics classrooms at Majac Secondary School. The students used the *Confident, shaky, relearn strategy-s*tudents asked each other what aspects of a question they felt confident about, what aspects they felt shaky about, and what aspects they need to relearn. When a student felt confident about a question, he or she can explain the question and mathematical validity of the solution strategy to the small group.

1. 80% of a number is 800. Work out the number.	**2.** Given that j : b = 9 : 1 and b : c = 9 : 10. Find the ratio j : b : c. Give your answer in its simplest form.
3. 20% of a number is 140. Work out the number.	**4.** Express 71995 as the product of its prime factors.

5.



In the diagram AC = 13 km and angle ABC = 30°.
Find the length of AB.

Figure 7. 2 Starter Activity

Planned lesson – Algebra 1 (simplifying, expanding brackets, factorising and solving). In this lesson we included micro strategies. Micro strategies included teacher actions in light of their more immediate effect. Using direct prompts as a micro strategy I gave the students the opportunity for reasoning (***socio mathematical norm: justification***) with and talk about mathematical concepts, procedures, and strategies using precise algebraic mathematical language (such as, expressions, equations, variables, coefficients). This communication plays a key role in helping students develop mathematical understanding. For example, as we (Ms Hanekom and I) walked around the groups, we asked questions such as, *How would you describe this problem using precise mathematical language*? *How would you describe your strategy for solving this problem using precise mathematical language*?

Through the structure of algebraic representations, I promoted the use of language that reflected mathematical structure and I encouraged students to use reflective questioning (Figure 7.3) to ***justify*** **(socio-mathematical norm)** how they solve the algebraic problems.

In the example below, a student completes the following task using reflective questioning (shown in the left column) to articulate his or her thoughts and reasoning (shown in the right column).		
Rewrite the following expression: $\frac{2x}{x-1}+\frac{3x}{x+1}$		
What can I say about the form of the expression?	It is a sum of rational expressions. I can think about rewriting this expression in terms of adding fractions, beginning with a common denominator of $x - 1$ and $x + 1$.	$\frac{2x}{x-1}+\frac{3x}{x+1}$ $\frac{2x}{x-1}\times\frac{x+1}{x+1}+\frac{3x}{x+1}\times\frac{x-1}{x-1}$
What do I notice about the denominator of each expression?	Both are binomials. The terms, x and 1, are the same, but one expression is the sum of these terms and the other is the difference. Binomials like these are factors for a difference of perfect squares.	$\frac{(2x)(x+1)}{(x-1)(x+1)}+\frac{(3x)(x-1)}{(x+1)(x-1)}$
What has happened in problems that I solved before?	Sometimes I was able to see common factors in numerators and denominators after adding two rational expressions. I won't rewrite the denominators yet.	$\frac{(2x)(x+1)+(3x)(x-1)}{(x-1)(x+1)}$ $\frac{2x^2+2x+3x^2-3x}{(x-1)(x+1)}$ $\frac{5x^2-x}{(x-1)(x+1)}$
Do I see any common factor of the numerator and denominator?	Neither factor of the denominator is a factor of the numerator, so I'll rewrite the numerator and the denominator.	$\frac{5x^2-x}{x^2-1}$

Figure 7. 3 Students Using Reflective Questioning

By asking themselves questions about a problem they are solving, students can think about the structure of the problem (***socio-mathematical norm: coherency / connections***) and the potential strategies they could use to solve the problem. First, I modelled reflective questioning to students by thinking aloud while solving the problem on the dry wipe board; I then wrote down the questions they ask themselves to clearly demonstrate the steps of their thinking processes; next I presented a problem and asked the students to write down what questions they might ask themselves to solve the problem. Students had the opportunity to practice the *think-aloud process* while working in the small group and shared their written ideas with each other. This process helped the students to use reflective questioning on their own during independent practice to explore algebraic structure (Figure 7.3).

Planned lesson -Shape and Space 1 (Solved problem structures and solutions to make connections among strategies and reasoning). In this lesson, I created opportunities for students to discuss and analyse solved problems by asking them to describe the steps taken in the solved problem and to explain the reasoning used. Specific questions were asked about the solution strategy, and whether that strategy was logical and mathematically correct. For example:

- What were the steps involved in solving the problem? Why do they work in this order? Would they work in a different order?
- Could the problem have been solved with fewer steps?
- Can anyone think of a different way to solve this problem?
- Will this strategy always work? Why?
- What are other problems for which this strategy will work?
- How can you change the given problem so that this strategy does not work?
- How can you modify the solution to make it clearer to others?
- What other mathematical ideas connect to this solution?

Asking these questions encouraged active student engagement. I varied the questions based on the needs of students and the types of problems being discussed. The questions above, presents general questions that could be applicable to many types of shape problems.

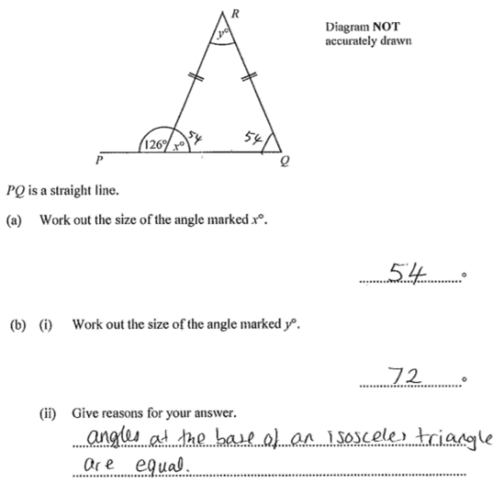


Figure 7. 4 Worked Solution for Discussion

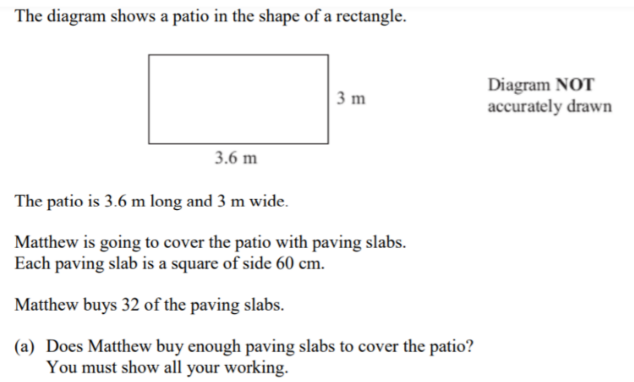
To foster extended analysis of solved problems I asked students to notice and explain different aspects of Figure 7.4's problem structure (above). The students carefully reviewed and discussed the structure amongst themselves in the small groups and each solution step of Figure 7.4 helped them recognised the sequential nature ***(socio mathematical norm: computational strategies*)** of solutions and anticipated the next step in solving the problem. This careful working and discussions improved students' ability to understand the reasoning (***socio mathematical norm*: justification)** behind different problem-solving strategies.

I provided further questions to facilitate discussion of the structure of problem (Figure 7.4).

- What quantities—including numbers and variables—are present in this problem?
- Are these quantities discrete or continuous?
- What operations and relationships among quantities does the problem involve? Are there multiplicative or additive relationships?
- How are comments used in the problem to indicate the problem's structure?

Students were then given two GCSE examination solutions to questions (Figure 7.5) whereby they had to individually work through two solutions and after 10-15 minutes feedback was taken from the group partners through *Partner coaching/Quiz*: the students quiz each other on the assigned problems/tasks. One student provided feedback on the solution and solution strategy while the other students, in the small group, used the questions (see above) to facilitate discussion of the structure of problem. Then they switched roles.

Question1:



The diagram shows a patio in the shape of a rectangle.

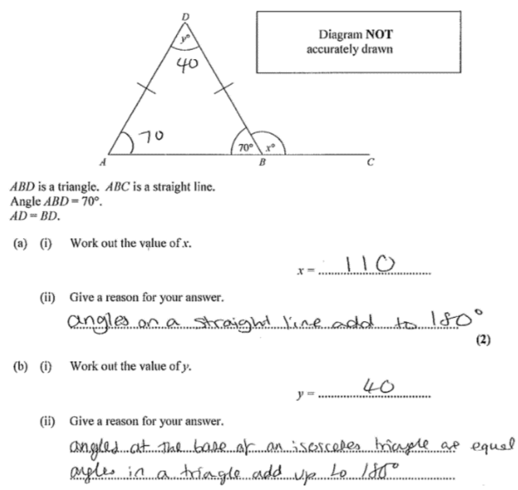
The patio is 3.6 m long and 3 m wide.

Matthew is going to cover the patio with paving slabs.
Each paving slab is a square of side 60 cm.

Matthew buys 32 of the paving slabs.

(a) Does Matthew buy enough paving slabs to cover the patio?
You must show all your working.

Question 2:



ABD is a triangle. *ABC* is a straight line.
Angle *ABD* = 70°.
AD = *BD*.

(a) (i) Work out the value of *x*.

x = 110

(ii) Give a reason for your answer.

angles on a straight line add to 180°

(2)

(b) (i) Work out the value of *y*.

y = 40

(ii) Give a reason for your answer.

angles at the base of an isosceles triangle are equal
angles in a triangle add up to 180°

Figure 7. 5 GCSE Worked Solution Questions

Functional Questions 2:

The students were asked to use the *Think, write, share* strategy; I gave students time to think independently about the problem (Figure 7.6) and write their ideas before they shared the ideas with their entire small group. As a whole group, the students identified the reflective questions that they naturally used to help their own thinking and to help their group partners and solve the functional mathematics task, below:

The diagram shows a patio in the shape of a rectangle.

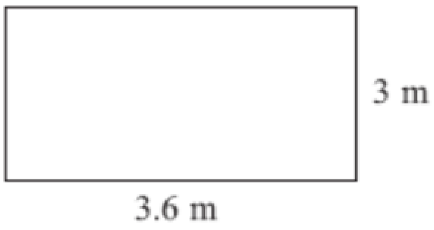


Diagram **NOT** accurately drawn

The patio is 3.6 m long and 3 m wide.

Matthew is going to cover the patio with paving slabs.
Each paving slab is a square of side 60 cm.

Matthew buys 32 of the paving slabs.

(a) Does Matthew buy enough paving slabs to cover the patio?
You must show all your working.

....
(3)

The paving slabs cost £8.63 each.

(b) Work out the total cost of the 32 paving slabs.

£ ....
(3)

(6 marks)

Figure 7. 6 Functional Mathematics Question

Plenary: Short Questions Set 4

At the end of the mathematics activity sessions the students were given differentiated questions (Bronze, Silver and Gold) to choose from. The students were asked to individually choose their five questions they would like to work on, it could be from Bronze, Silver and Gold, as long as they work on five questions. The students had 10-15minutes for this and Ms Hanekom and I observed how they decide which questions, then how they attempt the questions by using their mini whiteboards and then how they use strategies learnt to get to the solutions. Figure 7.7 display the questions the students choose from, and Figure 7.8 provided solutions to the questions.

★	★★	★★★
A1 $\frac{1}{2}$ of 6	B1 Solve: $3(8w+14) = 9(4w+2)$	C1 $-7.2 - -8.4$
A2 $\frac{1}{2}$ as a percentage	B2 Solve: $\frac{c}{10} + 1 \leq 5$	C2 Solve: $-6(-9n+23) = -6(-7+11n)$
A3 50% of 8	B3 -16×-8	C3 Increase 72 by $3\frac{5}{6}$
A4 The ratio of e to f is 1 : 3. The ratio of f to g is 3 : 5. Find the ratio e : f : g in its simplest form.	B4 If $\frac{1}{100}$ of an amount is 5, what is $\frac{1}{20}$?	C4 $1+1-\square = 1+0.5356$
A5 $\frac{1}{4} + \frac{1}{4}$	B5 $\frac{8}{11}$ of 110	C5 -117×-9

Figure 7. 7 Bronze, Silver and Gold Questions

★	★★	★★★
A1 3	B1 w = 2	C1 1.2
A2 50%	B2 40	C2 n = 1.5
A3 4	B3 128	C3 348
A4 1 : 3 : 5	B4 25	C4 $\square = 0.4644$
A5 $\frac{1}{2}$	B5 80	C5 1053

Figure 7. 8 Solutions to the Bronze, Silver and Gold Questions

The mathematics camp activities used very little direct instruction or modelling to promote multiple perspectives. This was likely because very little modelling was necessary.

Simple, *direct prompts* for additional perspectives were sufficient to elicit them. Even from the beginning of Phase One intervention, students appeared to understand what these prompts were requesting and responded to them appropriately while working in their small collaborative groups. Most of the times Ms Hanekom and I, purposefully introduced the various procedures through direct instruction and then allowed the students to further investigate why the processes worked. Next, I will discuss macro strategies through observations at the camp that revealed our teacher strategies were not limited to narrowly focused on micro strategies. I also planned for the groups' mathematical development over the two and a half days. The collection of broader teacher strategies that comprised this plan I have deemed macro strategies. Unlike the micro strategies, macro strategies did not directly support the productive norms per se. Rather, they indirectly supported these norms through establishing an overall conducive environment for the norms to emerge, equipping students with relevant tools and skills to help them practice the norms, and creating frequent opportunities for the norms to be expressed.

7.5 Macro Strategies

Through the first semi -structured interviews (in June 2013) with teachers they indicated that macro strategies were necessary during the beginning of the students' start at secondary school in order to establish a foundation for them to build on. Although the teachers spoke specifically about their classroom mathematical practices, in the following quotes, they revealed much about their general philosophy to teaching:

> DMvT: … *developing their analytical skills*, and…, it's things like *connecting* it to money. So, if you do stuff on decimals, I tend to do examples using money because they can see how that relates to them whereas if you just want to add up decimals, they don't really see the connection with real life.

> EMH: … *building up relationships*, … I think stands out…

SMA: …. *motivate* students … they turn to their teachers for advice and use their teachers for *motivation…*

In these quotes the teachers talked about how they *develop skills, build relationships and motivate* students at the beginning of the school year. The teachers recognised that the students need more 'foundation things' to be established first when they arrived at Majac Secondary School. Since many classrooms mathematical practices are similar to the productive norms outlined in Chapter Six, it is reasonable to conclude that many of the 'foundation things' that the teachers had in mind were relevant to the establishment of the productive norms as well. In the upcoming sections, I will systematically introduce and explain some the 'foundation things' that the teachers relied upon to establish the socio-mathematical norms. For explanatory purposes, I have decomposed these 'foundation things' into three macro strategies: conducive environment, foundational skills, and concept-oriented task philosophy. The conducive environment strategy helped to establish an overall, general environment that supported the socio-mathematical norms. The foundation skills strategy meant that Ms Hanekom and I taught students specific skills that allowed them to practice the socio-mathematical norms more effectively. Finally, our concept-oriented task philosophy yielded frequent opportunities for students to practice the socio-mathematical norms. In the upcoming sections, I will draw on interview statements from the semi structured teacher interviews as well as observational data to support my claims. After this, I will present a model which visually represents my macro strategies. Finally for clarification, I reiterate that the terms of conducive environment, foundational skills, and concept-oriented task philosophy were my creation for the purpose of organising and explaining the macro strategies that I witnessed.

Conducive Environment- The teachers in the study sought to create a classroom environment that is conducive for the productive socio-mathematical norms to emerge. They did this by creating a classroom where:

- Learning is exciting and fun
- Students feel safe
- Understanding is emphasised over performance
- The teacher knows individual students' strengths and weaknesses
- Helpful logistics and procedures are established

The teachers first macro strategy was to create a conducive classroom environment for the productive socio-mathematical norms to emerge. By calling this the 'first' macro strategy, I mean that this is the first macro strategy that I will discuss and not that this strategy occurred chronologically prior to the others. In the semi structured interviews, the teachers referred to certain environmental factors as foundational. This has been italicised in the quotes below:

> <u>EMH</u>: … in a *class* where the rest of the *pupils are thriving*. You need to look deeper into the bigger picture as to why they're not *engaging and succeeding*.
>
> <u>SMA</u>: … in their *classroom*, … *one-to-one conversation* there somewhere.
>
> <u>NMT:</u> … When they feel they are in *a protected environment,* and they feel they can *learn from their mistakes* without someone telling them off.

The italicised parts of the quotes indicate that, the teachers' overall classroom environment is a key part of the foundation they wish to establish at the beginning of the student's start to the school year at secondary school.

Overall, the macro strategy of creating a conducive environment passively supported the productive socio-mathematical norms. By 'passively supported', I mean that this macro strategy did not directly promote the norms per se, but instead promoted general student engagement with mathematics. Or put another way, a conducive environment worked to remove potential barriers that might prevent the emergence of the productive norms. By establishing helpful classroom procedures and making learning fun and exciting, the teachers in the study, worked to increase student engagement and remove the barrier of student disengagement due to boredom. By creating a safe atmosphere, they encouraged students to actively participate in classroom discussion and removed the barrier of fear of humiliation. By emphasising understanding over performance, the teachers helped students to think about the process of mathematical reasoning and removed the barrier of a competitive mentality. Hence, in this manner, a conducive environment laid a foundation for the productive norms to emerge.

Foundational skills

The teachers strived to teach their students foundational skills that allow them to engage in the productive socio-mathematical norms. To do this, they promote:

- Active listening
- Use of visual representations
- Use of precise mathematical language

The teachers recognised that complex mathematical practices implicitly relied on more basic, 'foundational' practices in order to function. They saw these foundational practices as necessary pre-requisites in order for the more complex practices to be successfully realised. In the following interview quotes, three teachers discussed and described necessary foundational practices:

<u>AMG:</u> … you *first need to build relationships* with.

<u>NMT</u>: … *being consistent in your approach*. Let all students know that they will receive the same treatment.

SMA: … students …be *engaged as they walk into a lesson*. They need something to get on *immediately as this will settle them down*.

These quotes lead naturally to the question of which foundational practices helped enable the productive norms in the teachers' classrooms. Observational data (June 2013) revealed three practices that the teachers used with their students that helped support the productive norms. Each of these foundational practices will now be discussed in turn, as well as how foundational practice enabled the productive norms. The first foundational practice that the teachers sought to promote was the norm of *justification*. Semi structured interviews with the teachers revealed that they viewed justification as a means towards establishing mathematical practices. In the following three interview quotes, lines referring to justification have been italicised.

SMA: … we did it in more in-depth … didn't understand, Key Stage 3 … … why certain things happened … now it made sense…

RMS: … when they're calm... they're focused, and they're motivated ...

EMH: … they learn well when there is challenge … clear direction… lessons are paced well … able to reflect and give feedback on the lesson …

In the quotes the teachers refer to *justification* as an in depth understanding of the work, referring to this as a more complex mathematical practice, as in KS3 it did not make sense but then in KS 4 it made sense. Another teacher stated that the attitude of the students changes ("when they calm") and justify their statement in stating when they "focused and motivated", as an example of a 'foundation skill' necessary for productive mathematical discussions to occur. In the third quote another teacher mentions justification ("… when there is challenge … clear direction… lessons are paced well") as an example of when the students learn well which helps enable more productive student mathematical activity. Therefore, the teachers saw *justification* as a means to establishing more mathematical goals rather than a goal in itself. This agreed with observational data, which indicated that justification functioned in a supportive and enabling role for the socio-mathematical norms. Thus, I found it reasonable to categorise justification as part of teachers' macro strategy of foundation skills.

The second foundational skill that the teachers promoted was use of visual representations. They believed that the process of representing numbers, operations, and problem situations visually was a skill that needed to be purposefully taught to students. They explained this in the following three interview quotes:

> RMS: … lessons related to sport and statistics in sport…
>
> EMH: … providing interesting and different tasks, keeping it varied … group tasks, functional activities, maths games all keep them enthusiastic.
>
> DMvT: … getting them to see it's about problem solving and puzzle solving and … connecting it to money... if you do … decimals … do examples using money … they can see how that relates to them.

Observational data showed that the teachers made an intentional effort during the lessons to teach their students how to visually represent mathematical ideas. In some situations, they introduced visual representations themselves through modelling, while in other situations, they directly prompted students to create them and then let individuals share their representations with the class. These visual representations then supported the three productive socio-mathematical norms. For example, students often *justified* statements/solutions by drawing and appealing to visual representations (see DMvT quote on decimals, above); through their representations, students found new ways of *conceptualising computations* (see EMH quote, varied tasks and functional mathematics); and the use of visual representations helped students to establish mathematical *coherency*. Reflecting on visual representations helped students to see how different mathematical concepts were related to each other (see RMS quote, on sport and statistics).

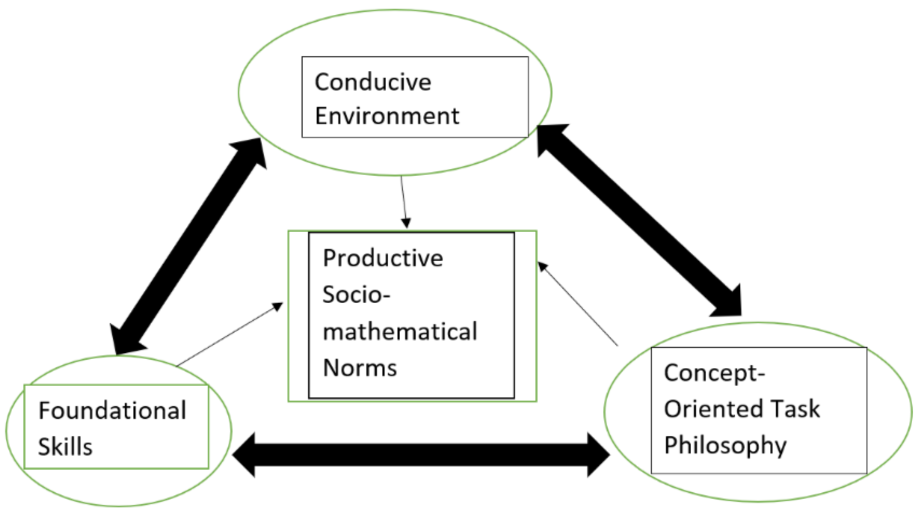
Use of precise terminology facilitated discussion of multiple perspectives, particularly when these perspectives were dealt with *computational strategies*. As the teachers mentioned earlier, terms such as, “group tasks”; “functional maths”; “puzzle solving”; “problem solving” and “connecting…” where these terms lead to different computational strategies in the students’ mathematical activities and discussions. Precise terminology also helped students to make *justifications* in certain situations. By clearly understanding the definition of relevant mathematical terms, students could then appeal to these definitions as part of a basis in justifying their claims. An exemplar of this occurred as Roan (a students in the study) attempted to justify:

RO: … I didn’t understand how to divide and when my teacher was explaining it to me, I understood it …

Terminology use, through the conversation with Roan, supported him (on a one to basis) and this helped him to understood division. In this manner, a clear understanding of relevant terminology aided the student in successfully making justifications.

7.6 A Model to Represent the Macro Strategies

In light of the macro strategies just discussed and the interactions between them, I put forth the following model, Figure 7.9, as a way to visually represent the macro strategies the



teachers in the study employed to support the establishment of the productive socio-mathematical norms.

Figure 7. 9 A Visual Representation of the Macro Strategies the Teachers Employed

The three ovals in the figure represent the three macro strategies that have just been discussed, while the box in the centre represents the three productive socio-mathematical norms identified in Phase One of the study. The arrows that point from each oval towards the central box represent the fact that each of the macro strategies helped to support the three productive socio-mathematical norms. How exactly each macro strategy supported the productive socio-mathematical norms was elaborated upon earlier during the discussion of the macro strategies in the preceding sections. Notice also in Figure 7.9 that there is a bidirectional arrow between each pair of ovals. This signifies that each macro strategy also helped to strengthen the other two.

In Summary, from previous comments, the macro strategy of a conducive environment meant creating an environment where learning was exciting, fun, and safe, where understanding was emphasised over performance, where helpful procedures were established. Through doing this, the teachers hoped to increase overall student participation in mathematical activity and discussions and to place the class's focus on the process of mathematical reasoning rather than obtaining an answer. Greater participation in mathematical discussions allowed students more opportunities to practice active listening and use visual representations. Therefore, a conducive environment passively supported foundational skills by allowing more frequent opportunities for students to practice their foundational skills. An emphasis on the process of reasoning, rather than performance, helped to support the teachers task philosophy of depth over breadth. Furthermore, a conducive environment also helped support the concept-oriented task philosophy. Previous discussions outlined that the macro strategy of student foundational skills consisted of the skills of active listening, using visual representations, and using precise mathematical terminology. The skill of active listening helped to support some of the procedures the teachers had established in their classroom, particularly the group tasks, functional mathematics procedures because the effectiveness of these procedures depended upon students listening to each other. The use of visual representations helped to emphasise conceptual understanding over against a performance-oriented view of mathematics by focusing students' attention on the mathematical structure inherent in the problem. In these ways, foundational skills helped to strengthen a conducive environment. Use of visual representations frequently helped students explore a mathematical task, for example decimals using money, in greater detail. This allowed them to see the mathematical structure of the situation and justify why these properties were occurring. Without the visual representations, it is questionable whether the students would have been able to recognise this structure and produce a *justification*. Thus, in situations such as this, foundational skills also helped to support a concept-oriented task philosophy.

I draw attention to the teachers use of concept-oriented task philosophy meant focusing on the mathematical concepts inherent in tasks, rather than simply focusing on completing numerous tasks or doing impressive tasks. It also structures a framework for the beginning of the secondary school year to develop skills and practices. This laying of the foundations' statements was intended to promote, among other things, use of visual representations through motivation, analytical skills and connecting. Hence, the concept-oriented task philosophy helped support foundational skills and it also led to the teachers in selecting tasks that were fun for their students.

7.7 Teacher Strategies in Light of the Mathematics Camp Intervention

This section addresses the teacher strategies implemented at the mathematics camp. Three norms were identified in Phase One: computational strategies, coherency and justification. It was discovered that the teachers used a combination of both narrowly focused strategies with a more direct, immediate effect (micro strategies) as well as broader strategies that focused on the class's long-term development and exerted a more indirect effect (macro strategies).

Ms. Hanekom and I used two micro strategies to establish the Phase One norms: direct prompts and modelling and we built on the three macro strategies, to support development of the socio-mathematical norms: creating a conducive environment, teaching students' foundational skills, and employing a concept-oriented task philosophy. These macro strategies synergistically supported each other and helped encourage development of the socio-mathematical norms by removing barriers to the norms' emergence, equipping students with necessary skills to participate in the norms, and providing opportunities for the norms to be practiced (See section 7.6).

7.8 Camp Evaluation

This section presents a discussion of the results. I will first briefly summarise the results. Second, I will address the dependence of the results on this particular mathematics camp intervention. Third, the final discussion about the camp, including implications, will be followed by a conclusion.

7.8.1 A Summary of the Results

Three socio mathematical norms were identified in this study; coherency, justification, and computational strategies. These three socio-mathematical norms were presented in Figure 7.1 within a Venn diagram to indicate their interrelated nature. To establish these norms, the teachers in the study, employed both micro and macro strategies. Micro strategies were narrowly focused and included teacher actions in light of their more immediate effect. Two micro strategies were identified: direct prompts and modelling which were used by Ms Hanekom and me at the camp. By contrast, macro strategies were broadly focused and included teacher actions in light of their long-term goals. Three macro strategies were identified: creating a conducive atmosphere, establishing foundational skills, and maintaining a concept-oriented task philosophy.

7.8.2 The Dependence of the Results on this Particular Mathematics Camp Intervention

What we can conclude from the results in this section is that it must be emphasised that the goal of this study is not to produce a generalisable theory of norms or norm development but to examine secondary school practice in relation to GCSE mathematics interventions for underachieving students in the UK and how the socio-mathematics norms supported this intervention.

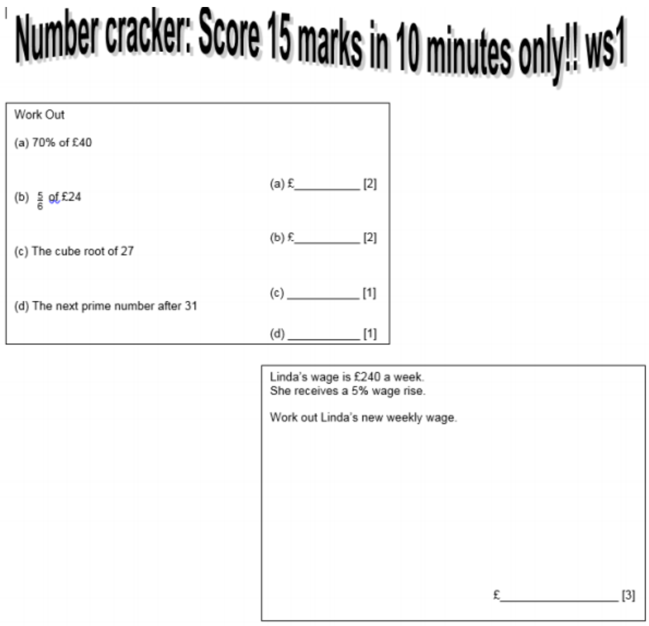
Amendments to the camp schedule were made throughout the duration of the camp to ensure that the students' experiences were as rewarding and enjoyable as possible. Observations on students during the mathematics camp indicated that active engagement with students was a worthwhile and enjoyable learning experience. Certainly, for some of the students, the camp was a new, enjoyable, motivational and exciting adventure. Three students stated:

SA: I have never been away from home on my own

HA: The activities …the climbing and ropes...I love it, I just love it

LO: To talk to other students you only see at school was really good.

In addition to focusing on student active engagement, I also focused on student actions that occurred specifically during small group mathematical conversation/discussion. Why small group mathematical conversation/discussions? This again is due to the inherent limitations in using group language. Group regularities are demonstrated by “almost everybody” (Sfard, 2007: p. 539) within the group. This means that the behaviour of a small group of the cohort (such as a pair of students) may not accurately reflect the norms of the entire cohort. To identify the behavioural regularities demonstrated by almost everybody, I must maintain my focus on the collective interaction of almost everybody. Therefore, one method of instruction that has been shown to increase student motivation and engagement is cooperative learning. The benefits of the cooperative learning method was appropriate for the mathematics camp intervention because it mirrors the real world of mathematics where mathematicians work together to solve complex problems, enjoy engaging in mathematical activities and display motivation in the problems and activities they attempt. Hence, Ms Hanekom and I amended the activities after listening to the students and allowed cooperative learning to increase student engagement and the resources used, impacted on more hand-on activities and real-life learning. The debriefing after activity one, gave Ms Hanekom and I the opportunity to change how the students approached the start to the activities, for example the Number Cracker (Figure 7.10) activity, as the students found it difficult and did not know where and how to start it. At first, the students just went straight to the five questions and started, with no guidance from the teachers.



Number cracker: Score 15 marks in 10 minutes only!! ws1

Work Out

(a) 70% of £40

(a) £________ [2]

(b) $\frac{5}{6}$ of £24

(b) £________ [2]

(c) The cube root of 27

(c) ________ [1]

(d) The next prime number after 31

(d) ________ [1]

Linda's wage is £240 a week.
She receives a 5% wage rise.

Work out Linda's new weekly wage.

£____________ [3]

Figure 7. 10 Students Five Questions

Figure 7.10 display real-life questions the students needed to engage with and feedback to the rest of the group without support from the teachers. I decided to introduce the activity to the students and gave them some guidance, such as modelling (*micro strategy*) a similar question on the board and showing the students step-by-step with follow on questions how to start the question.

Furthermore, the number lesson; real-life example questions, needed the students to discuss *justification* and decide which strategies, for example, use of manipulatives; drawings on their mini whiteboard or their fingers for counting *computational strategies* they will use and together agree what the solution to the problem would be and how they would present their answer. Muijs and Reynolds (2005) stated that teachers have identified peer learning as less threatening and as offering a basis for mutual learning, which supports achievement. However, peer learning is key, the importance of teacher subject knowledge in the preparation of teaching activities was clearly recognised by teacher and student (Ball, Lubienski and Mewborn, 2001).

The following statements of two of the students reflects that they needed teachers with mathematical subject knowledge (Evans, Jones and Dawson, 2014) to support them through their learning.

JU: … I … could not work out and find the area of a circle and then… my teacher helped me crack …I could suddenly do it

DA: …I had a … teacher … she just used to help you a lot and make lessons fun

These statements confirm that students see teachers fundamentally as the resources that would guide, support, care, for them when they need someone to rely upon.

Table 7.2 displayed the themes of active engagement and motivation, through the involvement of the students in a mathematics activity.

Table 7. 2 Key Findings from the Students' Discussion on Real-Life Questions

Intervention Question	Student	Action /Student Comments	Key finding / Theme
Real-life questions	Brook	Analysed question: ...*class discussions* Provided verbal comments and written solutions- ... *he'd come round explaining it, and showing us different ways how to work it out.* Approach to the question: ... *a starter, and then they have questions, and then they'll do... a game at the end that ... describes what we've done* Teamwork: ... *let the students have a go at trying to explain it to the class...*	*Active engagement:* through group involvement
	Julian	Reading and thinking about the question: ... *get up a poem. Or like a story or something, and then we'd read it and try and learn it and stuff.* Explain her thinking: ... *make the teachers more organised. ...when they ... organise their lessons ... fun activity. And we can all join in and just do like different stuff* Lead role in the beginning: ... *it's ... better to have practical, because it's more fun, and ... you see it for yourself.*	*Motivated:* through reflecting on questions
	Gray	Observe situation: ... *it just helps you learn it a bit better* Communicating verbally: ... *still be like positive. And enthusiastic.*	*Confidence:* shown through challenging others and *engaged* in discussion

From Table 7.2. First, the students were clearly demonstrating quite different 'selves' when interacting and this behaviour is best described by Dornyei (2009) which represents what characteristics an individual would like to have and the person he or she would like to become. Second, was the ought-to self that represents what qualities an individual believes they should possess, which could include social obligations, responsibilities, or morals. Dornyei (2009) called this concept the possible selves and therefore, the research suggests that a combination of the individual's characteristics, the social pressures derived from outside sources and a positive environment will lead to motivation to learn. Therefore, the findings from the five semi-structured teacher interviews and the five classroom observations revealed that the teacher participants believed that student successes related to factors such as:

• when they are able to reflect,

• one-to-one or small group intervention (...about three of us aside and he showed us how to do it,

• perseverance…

• taking part and contribute in conversations,

and,

• group discussion…

It was important to design activities aimed at investigating whether teachers recognised their own attributions and how these affect their mathematics teaching (Shores and Smith, 2010). Recognising student attributions could help teachers understand the causes behind their failure. As stated by the teacher participants:

• … a pupil's behaviour and attitude…
• … access what they don't know…
• ... think about what their goals are…
• … never give up on a student… and,
• … support in school…

were very important and played a formative role in reporting behaviour toward the failing or low-achieving student (Georgiou et al., 2002). Thus, the teacher participants realised their attributions played a vital role in the success or failure of their students.

Figure 7.11, below, displays a challenge to students' teamwork skills which allowed them to discuss their own approaches to learning and teaching.

Algebra lesson 1

2. Gurdip is n years old
Amy is twice as old as Gurdip

(a) Write down an expression, in terms of n, for Amy's age

Hannah is 3 years older than Gurdip
(b) Write down an expression, in terms of n, for Hannah's age.

Figure 7. 11 Algebra Questions for Teamwork Skills

Ms Hanekom spoke of group work as an approach that she often used in teaching:

> EMH: … group work, challenging tasks, problem solving, working together is good motivation for them.

To which, one of the student's stated:

> **SA**: … when we do group work it's nice if the teacher would let you, ..., go with your friends because you tend to have more fun time learning.

Consequently, during the camp the teachers engaged and encouraged the students to have dialogue with group members, showing their work and explaining it through the use of mini whiteboards and drawings if they (students) did not understand how to express themselves in words. This active engagement of students in the learning process was essential to obtain this type of engagement which required a much different classroom from the authoritative and teacher-centered traditional classrooms (Polya, 2002). The commitment to, and the interest in, the problems, especially on the second day, clearly demonstrated that the students engaged with the activities, were focussed and group work started to 'grow on them'.

7.8.3 Evaluation and Results Amendments

A key issue (and negative aspect) was caused by underestimating the time required to complete each activity adequately, together with a subsequent failure to build in time for debriefing at the end of each activity. The time students spend learning depends on their opportunity to learn (time allocated for learning) and their level of perseverance (time engaged in learning).

As the camp progressed, it did not take long to become aware that there were too many mathematics activities scheduled for the students. The activities were not, however, considered to be an insurmountable problem because it was easier to modify or remove activities than try to create worthwhile problems at a moment's notice. Branch (1999) and Wiest (2008) confirmed that, students improve their knowledge, skills and performance in mathematics through a mathematics camp when a range of different activities are provided. The *Six Mathematics Activity* (Table 7.2), was reduced to four choices A, B, E and F. On the third morning, students were assigned to one set of activities from the choices A, B, E and F and C and D were removed, as this activity was a repeat of activity B.

7.8.4 Students' Evaluation of the Camp

After the camp, back at Majac Secondary School, on Monday 14th March 2016 the students were invited to complete an evaluation form and the results are contained in Figure 7.12 – 7.16.

Figure 7.12 does not represent the feedback from the students at the time of the camp but when they had returned to school, the next day. In the first statement, 4% of the students (n=10) strongly agreed, 19% of them were agreed, 16% of them did not know, 33% of them were disagreed and 28% of them strongly disagreed. Therefore, 23% of the students felt that they did engage well with mathematics activities at the camp whereas 61% did not.

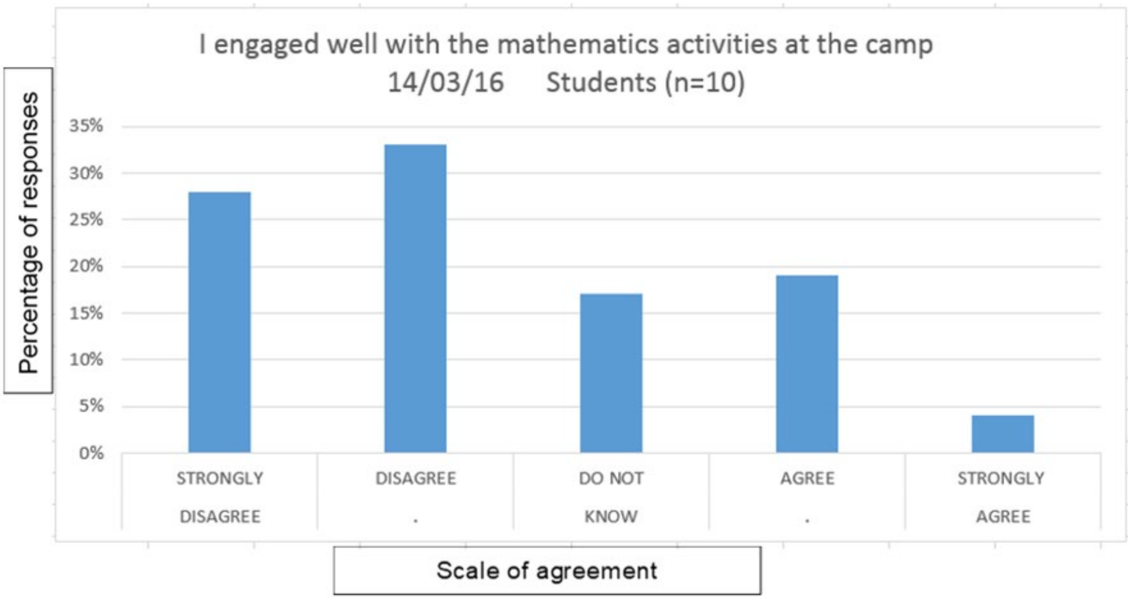


Figure 7. 12 Results from Mathematics Camp –Engagement with Mathematics Activities

The second statement, Figure 7.13, was ‘I engaged well with non-mathematics activities at the camp’. There were 60% of the participants who strongly agreed, 30% of them were agreed, 10% of them were did not know and none of them disagreed or strongly disagreed with this statement. Therefore, ninety-nine percent of students (n=10) agreed in question 2, that there can be little doubt the non-mathematical activities were successful. In comparison to Figure 7.12 90% of the students felt that they enjoyed the non-mathematics activities which indicates that the students engaged very well with these hands-on activities, while only 23% of the students engaged very well with the mathematics activities.

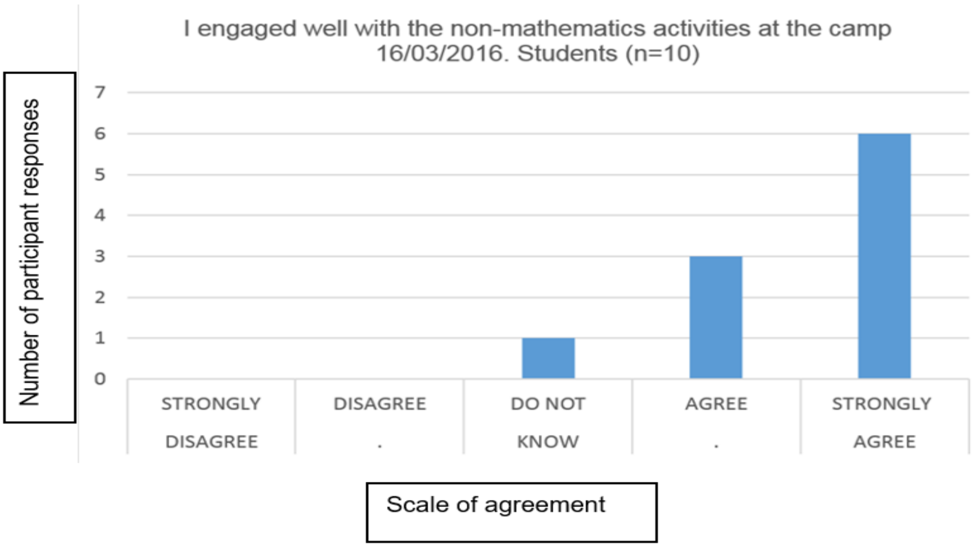


Figure 7. 13 Results from Mathematics Camp- Engagement with Non-Mathematics Activities

The third statement was 'I engaged cooperatively with mathematics activities'. Among the respondents 25% of them were strongly agreed, 35% of them were agreed, 29% of them were did not know, 5% of them were disagreed and 6% strongly disagreed. The responses to statement three shown in Figure 7.14 indicated that 60 percent felt their understanding of mathematics improved because of the cooperative working environment on the camp and the interaction with other students. This finding was significant, in that the students enjoyed group work, hands-on, interactive engagement as a real positive of the camp.

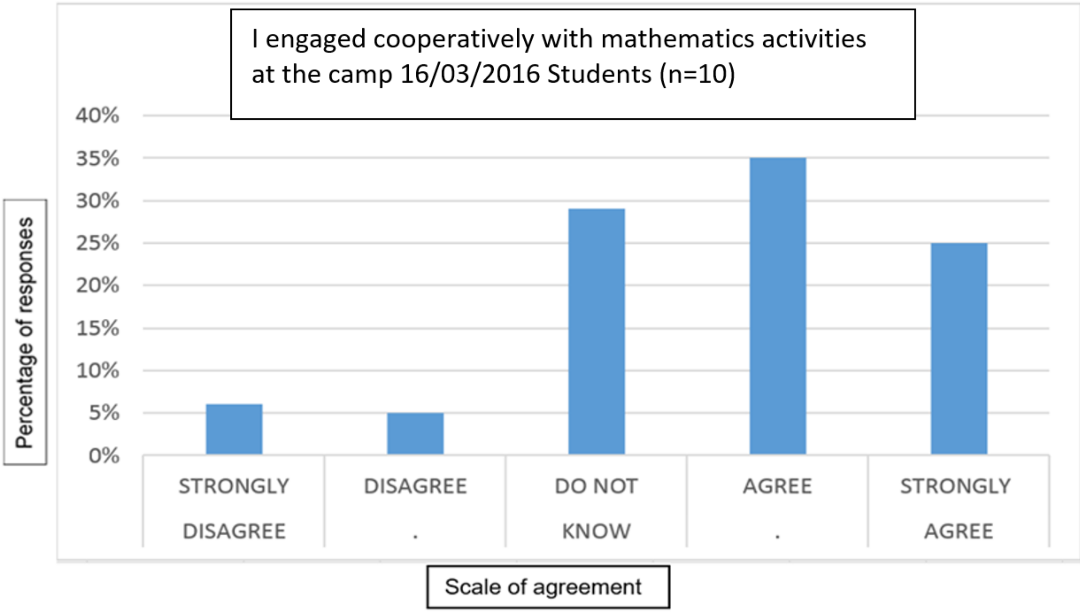


Figure 7. 14 Working Cooperatively with Mathematics Activities

The fourth statement was 'I learnt a lot of mathematics at the camp'. Three percent of the respondents were strongly agreed with this statement, 36% of the respondents agreed with the statement, 12% did not know, 33% of the participants disagreed and 16% of the participants strongly disagree.

The fifth statement 'discussing each activity afterwards helped improve my understanding of mathematics'. There were 9% of the participants strongly agreed, 56% of them were agreed, 17% of them were did not know, 11% of them disagreed and 7% strongly disagreed. Table 7.4 shows the summary of the five statements.

Table 7. 3 Students' Perception on Mathematics Camp

Statement Number	Statement	Percentage (%)				
		Strongly disagreed	Disagreed	Did not know	Agreed	Strongly agreed
1.	I engaged well with mathematics activities at the camp	28	33	16	19	4
2.	I engaged well with non-mathematics activities at the camp	0	0	10	30	60
3.	I enjoyed working cooperatively in groups	6	5	29	35	25
4.	I learnt a lot of mathematics at the camp	16	33	12	36	3
5.	Discussing each activity afterwards helped improve my understanding of mathematics	7	11	17	56	9

Table 7.3 indicates that students identified that they did not do well with the mathematics activities at the camp. Poor performances among students in mathematics are a common occurrence (NRC, 2001) as it generates a negative learning environment and creates hostility toward the subject. Too often students become irritable with themselves because they cannot grasp the concepts being taught. In turn, students refuse to ask questions for fear of asking about a problem they think everybody else understands. Furthermore, the numerical data, Table 7.3, showed the feedback from the students (n=10) when they were given small group tasks, they carried it out through engagement, discussion and visual drawing /representation (when needed). The students worked cooperatively and engaged with one another, and at times they individually found the solution to a question and then confirmed it with the rest of the group. Slavin, (2010) states with students "receiving 900 hours of instruction every year" (Slavin, 1984) and "learning environments for the 21st Century being ones in which students are actively engaged with learning tasks and with each other" (Slavin,

2010, p.10) teachers are consistently developing new ways to motivate students to do schoolwork. Hence, participants perceived that the mathematics camp activities were interesting, enjoyable and stimulated their interest in mathematics. They also agreed that the mathematics camp activities motivated them to learn mathematics. These findings were consistently observed by Ms Hanekom and I and we recorded this in our observational notes and afterwards discussed what we observed.

The students identified positive experiences with the mathematics camp, but most of them (n= 6) had a negative attitude before the camp (see comments below from focus group interviews)

RA: … you're kind of sitting there, and if you're bored by learning it, then it kind of just goes over your head, because you're not concentrating

DA: …. some of them just stand there and just talk at you…

SA: … hard to learn if you're learning yourself from the textbook. It's not really good to be honest…

due to the perceptions and myths of mathematics (Gadanidis, 2012), they are scared of mathematics (Sam, 2002) and they find mathematics "difficult, cold, abstract…" (Ernest, 1996). Furthermore, parents and significant others have a strong influence on students' beliefs and attitudes towards mathematics (McLeod, 1989). Students' mathematics learning outcomes are strongly related to their beliefs and attitudes towards mathematics (Furinghetti and Pehkonen, 2002; Leder, Pehkonen, and Törner, 2002; Pehkonen and Pietilä, 2003). According to Sam (2002) parents' views about mathematics have strong effect on the way they teach their children. These views often create tension between the parents and teachers if they share contrasting images of mathematics. These negative attitudes towards mathematics came through the students' responses to the key questions about engaging and learning with the mathematics activities at the camp.

Ms Hanekom and I provided non-textbook opportunities for engagement, cooperative groupwork, interactive engagement, but these activities did not immensely change the students' views and perceptions of mathematics. When the students engaged with the activities at the camp, we (Ms Hanekom and I) observed them actively engaged and focused; therefore, their feedback conflicts with what they have and what they did at the camp.

Furthermore, during the last five minutes of each session the teacher data collected demonstrated that drawing upon practical applications of mathematics with the intention of engaging students through the use of mathematics in 'real life' enhanced the students learning and enjoyment of the sessions. Therefore, the students expressed a strong level of enjoyment in the environmental activities at the camp, to which we agree with the students and a closer link between mathematics curriculum activities and environmental activities should be included in the planning of the sessions, for example, measuring trajectories of swings, or timing high-ropes completions. Overall, the participants were satisfied with the mathematics camp.

Jacobs' (2020) SEMISM portrays micro-, meso-, exo-, and macro levels linked together in a system of nested, interdependent, structures ranging from the proximal, consisting of immediate face-to-face settings, to the most distal, comprising broader social contexts such as classes and culture. For a student at Majac Secondary School the four levels describe the interwoven networks of transactions that create an individual's ecology. Therefore, the effectiveness of the mathematics camp had the potential to generate a significant deal of social change for the students and teachers involved and for the local community and this was a immense learning opportunity for the students and teachers.

7.9 Final Discussions About the Camp

Several students mentioned how their engagement and participation in the hands-on activities effected their motivation, were fun and enjoyable, and improved their understanding of the content during the mathematics sessions. Students consistently mentioned how they enjoyed the general nature of the hands-on activities because they were engaging, interactive, and visual. Ray mentioned: "that there were many interactive activities, so we were engaged and actually doing something" compared to normal classroom experiences. Students described the activities as fun because the activities were engaging and required them to participate. Sam liked "when we got up and we actually did like demos" such as the Foreign Exchange activity "some of us stood on the side and pretended to be tourist in a different country and then we actually convert our currency and had to work out the money back and that was fun as we got it sometimes wrong but getting up and actually doing it and learning it". Even though the activities were fun, students claimed it was a result of being engaged in the learning process, which kept them from, as Dakota described, "getting sleepy". Most of the participants (n=9) commented that they felt the hands-on part of the lessons kept them interested, engaged, and motivated to learn throughout the class. All ten students agreed that their participation in the activities kept their focus and prevented them from being bored. Alex explained how he was "really motivated to learn a lot when we had activities that involved us actually participating as individuals". Some students felt that using a good balance of teacher explanation and activities were necessary because each contributed different information to the class. Logan's favourite part of the class was how it was structured, "usually there would be a PowerPoint with notes and information and after all that was covered there would be an engaging activity like a demo where we would all take part and it would help illustrate some of the concepts we just learned." The hands-on activities were able to enhance the learning process for the students throughout the 2.5 days as reinforcement for the material presented.

Ms Hanekom and I, through our observations and engagement with the students, perceived that the mathematics camp provided opportunities for the students to take up various challenges. We acknowledged through their engagement and observations that the students seemed to enjoy the activities, were motivated to learn and enthusiastic in learning mathematics. We agreed that the mathematics camp benefitted the students by providing them opportunities to take part in various challenging and interesting activities. Furthermore, there was unanimous agreement amongst both, Ms Hanekom I that we tried to do too many mathematics activities. This was resolved by planning only one set of the activities A, B, E, and F in the morning or afternoon and allowing 90 minutes for completion of each set rather than one-hour and forty-five minutes. The remainder of the morning or afternoon could be used for reflection and participating in whole group activities, such as, interactive games, free time to each student.

7.10 Implications

In this section, the results of this study will be compared with the existing research literature. In the process, implications for researchers, teachers, and teacher educators will be discussed. The study has implications in three areas of mathematics education: curriculum development, professional growth and training of teachers and for future research.

All three norms identified in Phase One of this study have also been identified in numerous other studies as contributing positively towards mathematical discussions. McClain and Cobb (2001), Hufferd-Ackles, Fuson, and Sherin (2004), Staples (2014), and many other authors point out the importance of justification, both for the discipline of mathematics itself and for mathematical discussions. Nathan and McClain and Cobb (2001), Sherin (2002), *and* Nathan and Knuth (2003), note the importance of justification and computational strategies. Finally, the importance of establishing mathematical coherency has been highlighted by Corey et al (2010), the National Research Council (2001), and Yackel, Rasmussen, and King (2000). Many of these same sources also recognise the micro strategies that the teachers used: direct prompts and modelling.

In terms of curriculum development, one conclusion that could be drawn from this study is that it is not necessary to take the students to a camp; instead, the camp can be brought to the students. Most of what was attempted at the camp could be included as an additional teaching strategy within the school setting. Many of the activities could be carried out in the schoolyard or in the classroom, and the ideas of working in teams, discussing strategies, working cooperatively and debriefing could all be used on a regular basis in the classroom. Haylock (2010: p.16) sees mathematics as a creative endeavour in which “flexibility and imaginative thinking can lead to interesting outcomes or fresh avenues to explore for the curious mind”. Nevertheless, such flexible, creative and investigative approaches to mathematics take time, as Askew (2012) stated that extending thinking time is essential to give students time to think, ponder, rethink and arrive at some conclusions. He suggested that incubation and pondering time are valuable, and these approaches, while *messy* for some teachers, actually enrich the dialogue between teacher and student. Students have the opportunity to take intriguing problems home with them to share with the family.

While the norms and micro strategies that the teachers employed are already well-recognised in the mathematics education literature, the idea of macro strategies offers new insight. The very concept of a 'macro strategy' has not been well articulated in other longitudinal studies. Studies that document a specific group's development on a 'macro level' often do not consider teacher strategies on the same macro level. For example, in their yearlong study of a third-grade classroom, Hufferd-Ackles, Fuson, and Sherin (2004) developed a framework to describe the discursive trends of the class over time, thus allowing them to consider discussions from a longitudinal perspective. However, when discussing the teacher's role in this development, they focused on in-the-moment micro strategies, such as the nature and intent of direct prompts. Ms Hanekom and my macro strategy of decomposing mathematical practices into their fundamental skills and then systematically establishing these skills is a strategy that has received relatively little attention within the mathematics education literature. McClain and Cobb (2001) addressed this idea somewhat in their investigation of socio-mathematical norm formation in a first-grade classroom. They found that once students understood appropriate criteria to delineate between different solution strategies, they quickly began to comparing strategies, deeming some as efficient or easy. Thus, McClain and Cobb's study indicates that the ability to distinguish different strategies is a foundation skill for comparing different strategies. Ghousseini and Herbst (2016) have stressed the importance of decomposing mathematical practices as a means to help trainee teachers personally make sense of them. However, teachers can use such decompositions not only to personally make sense of mathematical practices, but also as a pedagogical tool to help plan the progression of mathematical activity in their classroom, especially near the beginning of the school year.

The intervention was rooted in constructivism and social constructivism. These theoretical approaches postulate that knowledge is actively constructed by the student, and that the social environment and the relationship between the individual and the environment were crucial to learning (Vygotsky, 1978). Woolfolk and Margetts (2007) indicated that students' interest in, enjoyment and excitement about what they were learning is one of the most important factors in education. They also indicated that when students' motivation levels were increased, they were more likely to find academic tasks meaningful. Hence, Mr Tromp used Bingo to ***engage*** the students' learning in his classroom. Furthermore, Ms. Hanekom stated:

> EMH: … ***motivation*** comes from an ***enthusiastic*** teacher. Group work, challenging tasks, problem solving, working together is ***good motivation***

The literature indicated that the perception of activities as meaningless was negatively correlated with happiness and well-being, and positively correlated with irritation and stress (Compton, 2000; Natvig, Albreksten, and Qvarnstrom, 2003). This might suggest that meaningful instructional activities and materials in interventions could help students develop more positive attitudes towards mathematics. Mr Tromp stated that he:

> NMT: … talk ***the importance of maths*** as a ***problem-solving skill …*** you ***need to practice***, and … that sort ***of systematic method of problem*** solving.

Therefore, in the classroom at school, employing at least some of the aforementioned effective practices have the potential to influence students' attitudes towards mathematics. Performance of students could be evaluated in the classroom by observation and discussion. As was demonstrated clearly at the camp, it was not necessary to use the implied threat of tests to motivate the students nor is a written test the only way to evaluate students' knowledge and understanding. For example, during the sessions at the camp the students were working in small groups cooperatively and discussing, agreeing/disagreeing, and then feeding back to the rest of the group without having to write down their answers in a test format. Kurlaender and Howell (2012) noted that many students attend secondary school with insufficient levels of academic quality and rigour, particularly in the core subjects of English and mathematics. The ACME (2010) stated that mathematics is a highly interconnected subject that involves understanding and reasoning about concepts and the relationships between them. It is learned not just in successive layers, but also through revisiting and extending ideas. As such, the mathematical needs of students are distinctive from their more general educational needs. For mathematical proficiency, students need to develop procedural, conceptual and utilitarian aspects of mathematics together. Canobi, Reeve and Pattison, (1998); and Baroody (1999) stated that proficiency is believed to result from understanding number operations, patterns, and principles. Baroody (2006) advocated that proficiency in basic calculation means accurate solution by any efficient strategy not just retrieval. Therefore, mathematics is essential to everyday life, critical to science, technology, and engineering, and necessary for financial literacy and most forms of employment. A high-quality mathematics education therefore provides a foundation for understanding the world, the ability to reason mathematically, an appreciation of the beauty and power of mathematics, and a sense of enjoyment and curiosity about the subject.

Knowledge of basic calculation solutions was equated with accurate retrieval. Students were credited with retrieving the answer based on a mixture of observation and self-report. Therefore, teachers could develop a personal learning checklist for each student (for example, Logan, Dakota, Hayden, Gray, Alex and Brook), who were in danger of not achieving their minimum expected target grade or the DfE's grade C/4. Hence, the findings from the teacher participants further elaborated on strategies and techniques that could be employed to support the students, such as:

- EMH: … *I often have a conversation, using aspects of maths, striving to achieve a* goal…
- RMS: … *teacher can have a very positive influence, productive school experience…*
- DMvT: … t*eacher effect, home is massively important …*
- NMT: … *questioning skills, discussion, rich questioning…* and,
- SMA: … *building relationships, show that you*

The camp provided motivating activities for the students, but it also proved to be a very valuable learning experience for all staff involved and the teaching of mathematics could be improved significantly if mathematics camps were held for teachers rather than students. Fosnot and Dolk (2001: p.159) suggested that "teachers need to see themselves as mathematicians," and towards this end they, the teachers, need to foster environments where they engage with mathematics and construct mathematical meaning. The mathematics experiences on the camp were designed to be interesting and challenging enough to capture the teachers' interest and imagination and to offer the potential for mathematical insight and surprise (Gadanidis, 2012). Furthermore, the collaborative environment fostered at the camp, allowed the teachers to work in small groups with students and it gave the teachers the opportunity to reflect on the sessions. In the last five minutes of each session, the teachers took the time to write about what they learned and what they felt during the session. This reflection helped the teachers see what other teachers learned and how they felt when doing mathematics with the students. Not only would the teachers gain experience in organising and running a camp, but they would also be exposed to a different approach to mathematics and mathematics education, which could be incorporated into the regular classroom environment. Shulman (1987: p.8) suggested that teacher education (and research) had "a blind spot with respect to content" and the emphasis was solely "on how teachers manage classrooms, organise activities, allocate time and turns, structure assignments, ascribe praise and blame, formulate the levels of their questions, plan lessons, and judge general student understanding". There is growing interest among mathematics teachers in what PCK could encompass. While teachers think that there needs to be a dialectical relationship between content and pedagogy, PCK define what mathematics teachers need to learn by trivialising what students need to learn. For example, PCK tends to be defined by saying that students need to know a mathematics concept like prime or multiplication in two ways perhaps, but a teacher needs to know it in more ways. Similarly, Ball (2003) suggested that teachers need to know the same things that they would want any educated member of our society to know, but much more their roots and connections, their reasons and ways of being represented.

Under the 2019, p.11 education inspection framework, Ofsted inspectors judge the personal development of students, and evaluate the extent to which:

> the curriculum and the provider's wider work support students to develop their character; including their resilience, confidence and independence; and help them know how to keep physically and mentally healthy.

The present study could have considered the implementation of the mathematics activities with recreational activities which would have an impact on students' personal development, health and welfare. Jacobs' (2020) SEMISM identifies that the cross over links within the levels (micro, meso and exo) supports the students learning and therefore the mathematics activities could have linked with recreational activities.

In terms of further research, it would be thought-provoking to develop a one-term or one-year project integrating cooperative learning, working together, sharing ideas and strategies, reflecting on solutions to problems as well as many of the activities from the camp into regular teaching lessons. Kagan and High (2002) stated that cooperative learning is considered as one of the approaches, which shows positive results in boosting the students results and in creating the best relaxing atmosphere in classrooms. Jolliffe (2007) agreed with Kagan and High (2002: p.3) and stated: "in essence, cooperative learning requires pupils to work together in small groups to support each other to improve their own learning and that of others".

Jollife (2007: p.4) stated the difference between group work and cooperative learning as follows:

> Group work itself is nothing new or magical. Traditionally, primary schools have often organized pupils to sit in groups of four or six, although [the] interaction between them may be very limited. The reason underlying this is the ethos of individual competition where pupils often complain: He's copying me! In this situation where pupils are not required to work collaboratively to complete a task, they would often be better working alone.

Cooperative groups are not like group work. In cooperative groups, students have to work together to achieve their mutual goals. Through the need to discuss tasks with each other and providing their team members with help to understand the work. Obviously, cooperative learning needs a regular process supported by a very comprehensive teaching programme of small group and social skills together with a lot of tasks and teaching techniques when used in a classroom (Jollife, 2007). The teachers in the mathematics department at Majac Secondary School could use the allocated half-termly departmental meetings as active hands-on workshops to develop new resources for all to use, pilot and implement new initiatives at KS 3 that would support the teaching in learning in KS4. Curriculum resources such as manipulatives or computer software have recently evolved to incorporate a profusion of online resources: websites, interactive exercises and more and more Open Educational Resources (OERs). This availability of OERs produces drastic changes in education and in teachers' work. This has been acknowledged for several years at the policy level (OECD, 2010).

For example, a text of the European parliament, following a report on new technologies and OERs by the Committee on Culture and Education states that:

> [The European parliament] emphasises that OERs create opportunities for both individuals, such as teachers, students, pupils and learners of all ages, and educational and training institutions to teach and learn in innovative ways; calls on educational institutions to further assess the potential benefits of OERs in the respective educational systems (European Commission 2013).

The use of resources and manipulatives helps students hone their mathematical thinking skills. The resources used at the camp, for example, mini whiteboards, flash cards, differentiated worksheets and flip chart paper had the advantage of engaging students and increasing both interest in and enjoyment of mathematics. Students who are presented with the opportunity to use manipulatives report that they are more interested in mathematics. Long-term interest in mathematics translates to increased mathematical ability (Sutton and Krueger, 2002). Stein and Kim (2009) states that resources and manipulatives can be important tools in helping students to think and reason in more meaningful ways. To gain a deep understanding of mathematical ideas, students need to be able to integrate and connect a variety of concepts in many ways. Through the cooperative learning discussions and small group tasks the students were able to engage in meaning mathematical dialogue with one another in relation to the different tasks presented to them. The students' ideas were laid out on the mini whiteboard and then they discussed which solution they would record as their final answer. Clements (1999) calls this type of deep understanding *Integrated Concrete* knowledge. The effective use of manipulatives can help students connect ideas and integrate their knowledge so that they gain a deep understanding of mathematical concepts. Teachers play a crucial role in helping students use manipulatives successfully, so that they move through the three stages of learning and arrive at a deep understanding of mathematical concepts.

The mathematics camp involved with this study was a two- and half-day programme that took place at the beginning of the summer term of the UK education system. Methods used to collect data: questionnaires, observations and teachers' notes. A questionnaire with five items on a five-point Likert-type scale (1= strongly disagree … 5= strongly agree) was used to measure students' responses towards the mathematics camp. The researcher's data analysis revealed that the program was successful in helping students experience a camp that supported their learning of mathematics through cooperative learning and hands-on engaged activities in small groups. To improve the effectiveness of the mathematics camp, an earlier placement within the summer of Year 9 should be considered (McMullen and Rouse, 2012). Instead of scheduling the camp to begin in the summer term of Year 11 when the students are under pressure from different subjects to achieve their best possible results. By having a small or non-existent gap of time between the mathematics camp in Year 9 and the beginning of the next school year when the students are Year 11 will give the students the opportunity to re-focus their mathematical learning and focus intervention strategies could be introduced.

The mathematics camp was identified as one of the approaches for academic intervention (Edwards et al., 2001; Wiest, 2008) in which students enhanced their knowledge, skills and results (Branch, 1999; Wiest, 2008) as well as quality outreach experience (Fox et al., 2004). However, the time spent on the mathematics activities could be reduced to ensure a more balanced academic versus outreach experience.

7.11 Chapter Conclusion

Chen and McNamee (2006: p. 109) suggested that not all students are the same, and that no "two minds work in the same way". Educational programmes, then, must be tailored for the individual and not presented in the heterogeneous manner that would fit the average class of students. Mattson, Holland, and Parker (2008) noted the need to provide multiple learning experiences for each student. Therefore, teachers should consider the unique needs of the students in order to meet the variety of learning styles and levels within or outside the classroom. This, then, suggests intervention is a process that teachers can use to better meet the needs of diverse students. The mathematics weekend away camp aimed to develop a planning framework that can be used by other mathematics teachers to develop and present similar interventions for students in their schools.

Perhaps the idea that students' attitudes could be changed in the short span of two and a half days was unrealistic. The contrast between the camp and the classroom was just too great and the environments so different, that any transfer of ideas or attitudes from camp to school was, probably, unlikely. However, the camp supported the idea of student achievement at GCSE through an intervention strategy. Therefore, the camp provided opportunities for attending students to experience mathematics outside the classroom, to explore different approaches to solving problems and to realise that the final answer is not necessarily the most important part of a problem. The camp also provided opportunities for students to work cooperatively on interesting problems and to have fun doing mathematics. These findings suggest that the Jacobs' (2020) SEMISM incorporated strategies which deliver many merits, especially from the perspective of the students in the study.

CHAPTER EIGHT: DISCUSSIONS, IMPLICATIONS, and LIMITATIONS

8.0 Introduction

The intent of this study was to answer the following central research question:

Given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?

The study also addressed its sub-questions:

1. *Why do students underachieve academically when the ability to achieve is present?*
2. *What were the key participants' perceptions of their successes and failures in the study?*
3. *What factors contribute to their psychological and academic needs?*
4. *Why is it important to empower able underachievers?*
5. *How can strategies and techniques help enhance student performance?*

First, I will present, briefly, the findings for the five sub-research questions and then return to the central research question. Then I will present the new knowledge the study offers and potential implications for practice. The limitations of the study will follow prior to the conclusion. Finally, I will consider several methodological limitations and end with a conclusion.

8.1 Findings for Sub-Research Question 1

Research Question 1 focussed on *why students underachieve academically when the ability to achieve is present?* The data analyses revealed that students underachieve because they give up and they do not have the repertoire of strategies that enables them to persist with being 'stuck'. Some students learned to engaged in real-life application of mathematics, peer teaching, active engagement (use of technology), and small group collaborative learning. Ms Hanekom and I witnessed a greater willingness for the students to persist when they were 'stuck' when at the camp they engaged with their peers, discussed their solutions with each other, used resources, such as mini whiteboards, to problem solve a question and they displayed confidence in answering questions posed. However, not all available strategies, including those listed above, were relevant to the intervention at the camp, for example, parental support, and peer teaching as these were developed through the Six Intervention lessons in Phase One.

The findings from the teacher participants elaborated on strategies and techniques that could be employed to support the students who get 'stuck', such as:

- having a dialogue about using mathematics;
- working towards goals;
- positive influences on engagement;
- home support; and,
- questioning techniques.

The mathematics camp intervention focused on activities that encouraged students to have conversations about engagement with mathematical concepts which had the intent of providing structure for steps to take when they were 'stuck'. When the students got 'stuck' the teachers encouraged them to ask other peers in the small group which they cooperatively engaged with before they asked the teachers. Although they were seen to struggle, Ms Hanekom and I saw that while the students were struggling, they were not giving up, which provides useful experience because learning is not conflict-free, and students gain skills from seeing confusion as something you go through; they need to see that clarity emerges from a good struggle and persistence has value. The students were using strategies, such as the mini whiteboard (as a resource to draw diagrams and clarify meanings), small group discussions (at their tables they engaged with each other) and they were listening to each other's explanations and then asked questions. These observations of the students (n=10) indicated that they were seen persevering more frequently with problems, trying different strategies to solve activity problems, instead of giving up. Furthermore, through their small group work, the students were challenged to *persevere* and *engage* with each other. An improvement in their ability to organise their work was observed, through discussions and observations with the students, in a way that would allow them to achieve higher marks in the GCSE examination, due to the changes in the style of examinations from 2017. This study suggests that overall, treatment in the form active engagement with students through a range of strategies would be beneficial for the students.

8.2 Findings for Sub- Research Question 2

The second research question focused on w*hat were the key participants' perceptions of their successes and failures in the study?* The students in this study agreed that the teachers' teaching strategies supported their learning and inspired them to become *motivated, challenged, engaged* and this could lead to *good assessment results*. The research project interventions focussed on the skills of how to work at mathematics. Many of the skills were introduced using active engagement and cooperative learning activities, such as the percentage lesson which was very *hands-on and engaged* all students.

On many occasions, during the focus group interviews and classroom observations, it was observed that the students' motivation *levels* were very low (a failure to succeed), and they needed encouragement to engage in secondary mathematics. In this case, it was found that what was missing was *real-life application* and we found that through peer teaching students were able to enhance the student learning and understanding of mathematical topics of others by relating the material to their personal contexts or making it 'real to their life'.

Student feedback from the mathematics camp indicated 23% of the students felt that they did engage well with mathematics activities at the camp, while 61% did not. The perception and views of mathematics influenced the students' decision about the mathematics activities at the camp; however, 60% of the students felt their understanding of mathematics improved because of the cooperative working environment on the camp and the interaction with other students. This finding was significant, as the students' perception of their success and failure seemed to depend on the type of activity. For example, where students had the opportunity to talk and work with their friends, undertake hands-on mathematics that was real-life, they felt that they were able to be more successful. If they were only engaging in tests or book work, they had less favourable views of their success.

8.3 Findings for Sub-Research Question 3

The third research question focussed on w*hat factors contribute to students' psychological and academic needs?* The data, from the teacher semi-structured one-to-one interviews and lesson observations, showed that non-cognitive predictors of achievement such as self-efficacy, academic motivation, grade goals and effort in classrooms contributed to student success in mathematics. For example, Mr Tromp used Bingo to *engage* the students' learning in his classroom and Ms. Hanekom used motivation through her teacher characteristic of being enthusiastic where she organised the class in groups when she gave them challenging tasks.

The factors from the students' perspective included the teachers' offers of help, having fun through engaging activities and knowing what they (teachers) were talking about. In relation to psychological factors (such as parental support, academic self-efficacy) the data showed that when Majac Secondary School created a positive school environment for the students, this helped them to combat academic stress and other challenges.

8.4 Findings for Sub-Research Question 4

The fourth research question focussed on w*hy is it important to empower able underachievers*? Classroom-level factors related to student empowerment were identified and among these, the data showed that the strongest connections were found between characteristics of the teacher-student relationship (teacher belief in student success and classroom sense of community) and the development of competence, academic and personal skills. These relationships emphasised positive caring and support, equitable power sharing and mutual dialogue. The ability of teachers to utilise classroom practices which engaged students was also a factor in student empowerment. For example, the data showed from teacher interviews: '*I try to be a role model',' my love for maths',* and '*I would like to help students to turn around from their circumstances*' indicated that teachers' expectations of the students were high, and they would support them in achieving those (Morisano and Shore, 2010). Hence, teachers' comments stated that they think about how they can reach the students and at times it is challenging, and they (the teachers) need to know more about the students. The teachers do not expect a perfectionist or a fearful student who thinks that their best was ultimately insufficient and lead to underachievement; rather a student they could work with and improve their progress in mathematics. Furthermore, the teachers also indicated that they really want their students to succeed in life and with the correct support *and* intervention, they can get through to the most challenging student in their classes. This statement reflected the importance of improving student-teacher relationships, as well as students' attitudes toward school and teachers.

Student data identified that some teachers (n=2) displayed '*low motivation'* towards their learning and therefore the students were struggling with learning mathematics. The focus group students were asked *'how do teachers help you feel like you are capable of doing work?'* One student stated that the teacher can go around the class to every student and the questions they do not understand can be explained and simplified. The student identified that some teachers were not going around and supporting students particularly at times when they are 'stuck'. They would welcome the teacher identifying their weaknesses and to make a note of it subsequently spending more lessons on the weak areas to support their learning and understanding.

8.5 Findings for Sub-Research Question 5

The fifth research question focussed on h*ow strategies and techniques help enhance student performance?* The data showed that at the mathematics camp Ms Hanekom and I adapted the mathematics lessons to 'real-life application'; 'engaged lessons; small group work'; 'showing' how to approach 'difficult/challenging' problems; and, having 'patience' with students who struggled in the mathematics class. Furthermore, we 'encouraged conversations' related to the 'interest' of the students which led to the students taking 'responsibility' for their learning.

The data from the students showed that they wanted to see how mathematics was used in *real-life*, and they stated that they would value lessons where they can learn life skills; for example, paying tax bills, water bills, as you need these skills when you leave school in order to keep control of your money.

Furthermore, data from the focus group interviews indicated clearly that the classroom environment significantly influences students' persistence and success in mathematics. The teacher's influence and encouragement played an important role in students' achievement. Although teachers encouraged their students positively, some students indicated that the teacher's learning style differed from teacher-to-teacher. Thus, meaningful instructional activities and materials in interventions helped students develop more positive attitudes towards mathematics because they became more reliant on their own skills and approaches. Teacher data stated that they (teachers) always refer to the importance of mathematics as a problem-solving skill and that the students need to practice these skills as everything in mathematics follows a systematics method in problem-solving.

These findings suggest that intervention initiatives have resulted in a degree of change at the level of the teachers themselves, although there was also some evidence of continuity of existing practices.

8.6 Addressing the Central Research Question

Having outlined the main findings of the sub-research questions of the study, it is time to return to the central research question with which this study is concerned.

The first part of the research problem addresses *why and in what ways do students underachieve and disengage in mathematics* and the data showed that although mathematics curriculum design plays an intervening role overall, the working practices of teachers in this study provide for achievement and success mainly in response to expectations from the multipart exo level (Jacobs, 2020 SEMISM). For example, this is evident in pedagogical content knowledge, teaching methods, motivation, self-efficacy, classroom management, subject content knowledge, recruiting and developing qualified mathematics teachers. It would appear that *teachers' subject knowledge* and *motivation* are major factors in students being successful at GCSE examinations. Although the evidence revealed teacher characteristics were important, findings reflect that teachers using high active engagement strategies with the students more likely supported successful learning in mathematics.

At the macro level, data showed that technology enhancements have changed what is taught, learned, and assessed in mathematics. For example, students stated that they prefer '*working on the interactive whiteboard, going to the computer room'*. The theme of active engagement and motivation through technology enhancement in the classroom and Phase One intervention (Intervention Lesson Four) are some of the most important affordances of technology-enhanced mathematics instruction. Harnessing them to support student achievement is a major challenge in mathematics education and this study would seem to support these findings (as noted throughout Chapters Four to Six).

The second and final part of this overarching research question aimed to examine *what, if any, has been the impact of interventions on students and teachers?* Findings in the study suggest that students and teachers draw on the Jacobs (2020) SEMISM for example, in the exo level, the Pedagogical Knowledge and Subject Content Knowledge of the teachers had an effect on the meso level factors, such as, contextual, content-based knowledge, teacher-parent relationships and engaging with mathematics which influenced the micro level (the student).

In Chapter Six, it was proposed that effective pedagogical approaches and subject content knowledge was important when teachers engaged their students in problems which enabled them to make connections between the areas of their learning and the findings of the study reflected this. One way of providing pedagogical knowledge was when Ms Hanekom and I changed the six interventions lessons in Phase One to more hands-on, engaged, interactive lessons that motivated students and influenced classroom management. The students' own strategies, such as engaging with their peers collaboratively and using mini whiteboards for effective communication, were important and they were 'ready' to learn mathematical ideas at the mathematics camp. Opinions and views expressed by both teachers and students confirm that this approach benefited learning. Interventions in secondary mathematics is one of many aspects supporting students to be successful at GCSE examinations.

Furthermore, the data revealed that at the beginning of the study, the students (n=10), were not accustomed to approaching a problem or an investigation with successful strategies. In their experience solving mathematical tasks had normally meant following certain given procedures. A required answer to a mathematical task had usually been one number or expression, or sometimes a simple answer given by a word or two. In that respect, the students had not, except on some rare occasions, been asked to do observations and to describe phenomena in mathematics. When investigating mathematics, students need to approach questions in different ways than when just exercising tasks similar to what the teacher has just shown or that can be found in textbooks. Thus, *socio-mathematical norms* were developed in the interactions of the two intervention phases:

- In the small groups, the students were producing the socio mathematical norm: *justification*, through discussions which showed agreement. In addition, Yackel, (2001), Yackel and Rasmussen, (2002) states that in small- group discussions students justify their claims, and discussions are expected to express disagreement. Hunter (2007) suggests that arguing and disagreement are important foundations for further shifts toward mathematical argumentation. On the other hand, there were times when certain students, for example, Dakota and Harry, in the group were producing the norm: through the justification of mathematical claims in the authority of their voices when they conveyed their opinions and solutions to a problem.
- The mathematics content, of the Six Intervention lessons and the mathematics sessions at the camp, contributed to the clarity and *coherence* of sessions/lessons. Because much of the content was carried through the mathematics problems of the session/lesson, the clarity and coherence of sessions/lessons influenced the way in which the problems within sessions/lessons were related to each other and how the students interacted with these problems throughout the sessions/lessons (Hiebert et al., 2003).

- Through using *computational strategies* in Phase One and Two interventions the students build numerical reasoning and made sense of computations. For example, Ms Hanekom and I, used number talks in the sessions/lessons for students to practice and share their mental mathematics and computation strategies (Parrish, 2011).

There are similarities in socio-mathematical norms negotiated and produced in my data with norms reported in the literature review that appear in traditional classrooms. Two norms that I did not find for, are about the need for a profound and creative approach and about the importance of following certain rules for method, accuracy and writing down the solution. The latter may reflect the context of English secondary mathematics. In the GCSE examinations, students are penalised for errors in accuracy, incomplete reporting of the solution method or using other than symbolic methods. I would think that the former is an important norm negotiated in the transition from school mathematics tradition, where solving tasks according to instructions is the main activity, to an inquiry mathematics tradition, where students are required to explore and create mathematics. It may be, however, that the activity of investigating mathematics in my study is a significantly different activity than creating solution methods for clear tasks in realistic mathematics education.

Therefore, through my research, I have come to understand that applying new approaches in naturalistic settings is a job on its own, as I went to the students and teachers, and gather sensory data; what is observed and felt. There is no shortcut to success, here. But I have also learnt that it is possible for you to change instruction in schools, especially if you are a teacher. Teachers need to know about new innovations, construct it themselves or let it arise from their practice. They need understandings of developmental work in the context of a school, what kinds of aspects are involved and are important in the change. In addition, on the basis of my experiences about the ease of students giving up, I see that very often a certain kind of agreed commitment between teacher and student is needed for really making an impact. A planned project with researchers or other teachers, or just with yourself, as well as someone responsible for steering the project until its goals are achieved, would create a project structure that supports completion. We need to be open-minded because we may have to change our beliefs as well as our practice. In addition to changing our practices, the new approaches may require changing our deep beliefs (Richardson and Placier, 2001), epistemological orientations (Connolly, 2011) or our values. Reflection in the form of discussions with others, reading literature or writing is necessary. A teacher planning developmental work should think about organising a supportive network for her/himself. Indispensable dispositions are friendliness, respect for others, patience and persistence. If you are ready to work hard, this kind of developmental work at schools is a rich way of living with plenty of satisfaction. Therefore, it is a professional way of working as a teacher (Kincheloe, 1991) as it became a very important focus of the study since the findings were indicating that how we learn and engage in mathematics was as important as the conceptual understanding.

8.7 Findings

Three socio-mathematical norms (coherency, justification, and computational strategies) were identified. These three socio-mathematical norms were presented in Figure 7.1 within a Venn diagram to indicate their interrelated nature. To establish these norms the study employed both micro and macro strategies. Micro strategies (direct prompts and modelling) were narrowly focussed and included teacher actions considering their more immediate effect. In difference, macro strategies were broadly focussed and included teacher actions considering long-term goals. Three macro strategies were identified: creating a conducive environment, teaching students' mathematical skills, and employing a concept-oriented task philosophy.

8.8 Implications

In this section the results of the study will be compared with existing literature. In the process, the gap in knowledge that it fills and implications for researchers, teachers, and teacher educators will be discussed.

All three socio-mathematical norms identified in this study have also been identified in other studies as contributing positively towards mathematical discussion. McClain and Cobb (2001), Sherin (2004), and Staples (2014), Hufferd-Ackles, Fuson, and many other authors point out the importance of *justification*, both for the discipline of mathematics itself and for mathematical discussion. McClain and Cobb (2001), Sherin (2002), and Nathan and Knuth (2003), note the importance of computational strategies. Finally, the importance of establishing mathematical coherency has been highlighted by Yackel, Rasmussen, and King (2000); the National Research Council (2001) and Corey, et al., (2010). Many of these same sources also recognise the micro strategies that the teachers used: direct prompts and modelling.

While the norms and micro strategies that the teachers employed are already well-recognised in the mathematics education literature, the idea of macro strategies offers new insight. The very concept of a 'macro strategy' has not been well articulated in other longitudinal studies. Hufferd-Ackles, Fuson, and Sherin (2004) developed a framework to describe the discursive trends of the class over time, thus allowing them to consider discussion from a longitudinal perspective. However, when discussing the teacher's role in this development, they focused on in-the-moment micro strategies, such as the nature and intent of direct prompts. Other longitudinal studies allude to presence of macro strategies, but these strategies often do not receive much explicit attention, for example, Sherin's (2002) study. Wood (1999) investigated how the teacher helped her students to learn the practices of mathematical debate. McClain and Cobb (2001) investigated socio-mathematical norms in a first-grade classroom and found that once students understood appropriate criteria to delineate between different solution strategies, they quickly began to compare strategies, deeming some as efficient or easy. Thus, McClain and Cobb's (2001) study indicates that the ability to distinguish different strategies is a foundation skill for comparing different strategies. Ghousseini and Herbst (2016) have stressed the importance of decomposing mathematical practices to help trainee teachers personally make sense of them. However, the case of the teachers in the study implies that they can use such decompositions not only to personally make sense of mathematical practices, but also as a pedagogical tool to help plan the progression of mathematical activity in their classroom, especially near the beginning of the secondary school year. Through the Jacobs (2020) SEMISM the study sought insight into the development of individual factors which may vary across learning environments, such as the classroom. Classroom Environment, or perceptions thereof, are related to both self-efficacy beliefs and mathematics achievement, and display in the micro level factors that are close to the student, which have very clear links to achievement and progress, for example: student beliefs, students' attitudes, attitude towards achievement, student progression, attitude towards related subjects and attitude towards student confidence, teacher approaches and traditional teaching methods.

The teachers' concept-orientated task philosophy raises intriguing questions about the relationship between a teacher's Content Knowledge and their task philosophy (Cohen, 1990). Williams and Baxter (1996), Clement (1997) *and* Nathan and Knuth (2003), all described teachers whose main goals for their mathematical tasks seemed to be social in nature. Williams and Baxter (1996) noted that their teacher emphasised students working in groups and presenting their work to the rest of the class. Based on observations, they concluded that for at least some of the students, "discussing mathematics with other students rather than understanding mathematics was the purpose of group work" (p. 34). Nathan and Knuth's (2003) teacher sought out tasks that encouraged student participation and student-led discussions. In a reflection however, the teacher realized that she often focused on student-to-student interaction and "wasn't always thinking about the math" (p. 200).

At the mathematics camp, our goals for mathematical tasks were to engage students, cause them to ask questions, listen to each other, and build upon each other's ideas. While the goals from these various sessions were all arguably commendable, they were not mathematical in nature. Student interaction, student presentations, group work, and asking questions are all social goals that do not specify how, if at all, students are interacting with mathematical ideas. Therefore, our task philosophies were socially oriented. Ms Hanekom's mathematical content knowledge was less than ideal, and she needed support with the development of her Subject Content Knowledge. Nathan and Knuth (2003) reported that their teacher's content knowledge "was lacking in some major areas" (p. 181), Williams and Baxter's (1996) teacher "expressed some concern regarding her ability to teach the mathematical concepts" (p. 28), and Clement's (1997) teacher saw no inherent difference between mathematical discussion and discussion from any other subject area. By contrast, our task philosophy was concept oriented. Rather than trying to complete tasks or foster certain social interactions, our overriding goal was to highlight the key mathematical ideas underlying the tasks' activities. To do this however, Ms. Hanekom had to possess the necessary Subject Content Knowledge to understand what the main mathematical ideas of the task were and how they related to other mathematical topics and ideas. Staples (2007) also observed a teacher who appeared to hold a concept-oriented task philosophy. She noted that "an overarching theme in [the teacher's] work was that she fostered students' thinking about the problem and not their progression towards task completion" (p. 33). Furthermore, Staples also noted that the depth of her teacher's content knowledge was "quite remarkable" (p. 36). Collectively, these studies lend support to the idea that lacking Subject Content Knowledge, teachers tend to adopt nonmathematical goals for their tasks. Wilhem (2014) found that teachers with less mathematical content knowledge were more likely to lower the cognitive demand of a task during implementation. It would certainly be reasonable to conjecture that a teacher with less content knowledge, such as Ms Hanekom, tend to adopt nonmathematical goals for their tasks and then, as a result, lower the cognitive demand of the task. For example, if a teacher has a task-oriented task philosophy, they would likely be willing to lower the cognitive demand if students' progress was too slow so that the task could be completed in a timely manner. This was evident at the camp as we had to change the activities from six to four. More research is necessary to investigate the interaction between teacher content knowledge, task philosophy, and the cognitive demand of task implementation.

Ms Hanekom and my concept-orientated task philosophy also contains implications for both teacher and researcher educators. The assumption is commonly made within mathematics education that higher-level tasks that engage students in complicated, unusual mathematical thinking, must be long and somewhat vague in their setup. For example, Stein, Grover, and Henningsen (1996: p .462), in their seminal work on the levels of cognitive demand, stated that:

> High-level tasks are often less structured, more complex, and longer than tasks to which students are typically exposed… Students often perceive such tasks as ambiguous and/or risky because it is not apparent what they should do and how they should do it.

Wilhelm (2014) implied that a single class period of 45 minutes may not provide enough time to complete a high-level task. Munter (2014) observed that most high-level tasks are often characterised by three phases: the launch phase, where the teacher explains the task, the explore phase, where students are given time to investigate the problem, and the summarise phase, where the class resumes to discuss the task in whole-class discussion. All these authors imply that achieving high-level, non-routine thinking is likely to require more class time than traditional mathematical activity. At the mathematics camp the high-ability students were placed in a small group with a middle and lower ability student and the high ability student used their high-level mathematical thinking to support the group in accomplishing the short activities. For example, a high ability student mentioned to the rest of his group that the foreign exchange question required calculations, it probed their understanding more conceptually. This conceptual understanding led to a discussion about how to proceed with the activity and the middle and low ability students were guided and supported by the high -level thinking from the higher ability student. In this instance, high-level mathematical thinking was elicited from the student. By Stein, et al's (1996) description, these tasks were high-level, yet were relatively short and focused. Students did not perceive them as ambiguous because they understood what was being asked of them. The case of the discussion between the students implies that teachers and researchers alike could investigate how high-level mathematical thinking can be elicited from shorter, more focused tasks and activities.

Ms Hanekom and my *concept-oriented task philosophy* used at the mathematical camp contains further implications for researchers to investigate the relationship between students' content knowledge, their experience with mathematical practices (for example, using their content knowledge), and their ability to engage in high-level mathematical tasks. Teachers and researchers alike have given much attention to task selection and implementation considering students' prior mathematical knowledge. For example, Henningsen and Stein (1997) point out that a task that is too far removed from students' prior mathematical knowledge will limit their ability to engage in high-level reasoning. To be successful, tasks need to build appropriately on students' current level of mathematical content knowledge. However, comparatively little consideration has been given to selecting tasks in light of students' proficiency with the requisite mathematical practices. For example, assume that a high-level task requires students to justify. Even if students have the necessary mathematical content knowledge, they may have little experience with the actual practice of justifying. This lack of proficiency with a mathematical practice could potentially limit students' ability to draw on and use their content knowledge. In his investigation into the process of proving, Karunakaran (2014) found that expert provers used similar content knowledge as beginner provers but in more sophisticated ways. He suggested that the experts' additional experience with proving allowed them to access and retrieve their content knowledge with greater ease than the beginners. This supports the notion that researchers and teachers need to draw a distinction between students' content knowledge and their experience using that content knowledge to engage in mathematical practices such as generalising, justifying, interpreting notation, and creating visual representations. Through many of the tasks in Phase One and Phase Two we allowed the students to practice using their content knowledge to generalise, justify, and establish mathematical coherency. By choosing familiar and comfortable mathematical topics, we allowed the students to focus solely on these practices without being hindered by a lack of content knowledge. Our success in establishing mathematical practices in classrooms implies that researchers should investigate in greater detail the relationship between students' content knowledge and their experience with mathematical practices (using their content knowledge) and how each of these areas allow them to engage in high-level mathematical tasks.

The review of literature further revealed that while useful research has been completed at the national level in this area, much less has been completed at the institutional level. These gaps include limited literature on engaging students with mathematics, a tendency for research to focus on the barriers model to broadening of access and a lack of interventions and a lack of evidence on the challenges and merits of working in partnership with the students.

Constructivism reviewed

Constructivism was introduced and discussed in detail in Chapter One. Interestingly, both interview and observational data did not indicate that constructivism was present at our delivery of the sessions at the mathematics camp. We were certainly successful in involving the students in meaningful mathematical discussions. As the norms from Phase One indicate, the students regularly justified, established mathematical coherency, discussed computational strategies, and offered their own perspective on whatever topic the group was discussing.

Throughout my discussion with the students, I never felt any tension between student informal participation on the one hand and rigorous mathematics on the other. I argue that the presence, or absence, of constructivism is a direct result of how we personally frame the issue of student discussion. Many teachers and researchers have framed discussion by its quantity and its form (for example student-to-student, student-to-teacher, teacher-to-student). Examples of this can be found in Yackel, et al (1991); Nathan and Knuth (2003 and Hufferd-Ackles, et al (2004). Many teachers have succeeded in increasing the quantity of unproductive student discussion (Williams and Baxter, 1996). Furthermore, a natural teacher response is to decrease their own participation in discussion and refrain from dispensing information in order to allow students a more active conversational role.

There was no indication that Ms Hanekom and I personally framed discussion in terms of quantity or form. Our role in classroom discussions were varied. At times we played a more passive role, insisting that the students supply ideas. However, we also frequently assumed an active role, giving no sign of hesitation or reluctance in the process of doing so. We wanted the students to participate in specific mathematical practices such as justification, making connections between different representations, and using various computational strategies. For these reasons, I conclude we framed discussion in terms of student engagement in mathematical practices, and that this subsequently allowed us to avoid constructivism. Therefore, a focus on student engagement in mathematical practices naturally led us to consider the content of student discussion rather than the complete quantity of it. This, in turn, allowed us to avoid the commonly employed teacher strategy of minimising our own role in discussion in an attempt to maximize our students' role. At times, I persistently pressed students for their reasoning, showing almost a tenacious insistence that certain ideas be student voiced. However, I also utilized direct instruction, which enabled student participation in mathematical practices. For example, Ms Hanekom used direct instruction to introduce non-standard multiplication algorithms to the small group students in a fairly procedural manner. She then had students' discussion in the small groups to justify why these various algorithms worked. After a period of investigation, the groups then shared their insights with the rest of the students at the camp. Thus, Ms. Hanekom 's active role in direct instruction ultimately allowed students to engage in mathematical reasoning and practices. Rather than minimising her own role, Ms. Hanekom continually adjusted the prominence of her role as necessary to assist student involvement in the desired mathematical practices. Therefore, based on our intervention sessions at the camp, I assert that framing student discussion in terms of mathematical practices is more helpful than framing it in terms of quantity or form of discussion.

Furthermore, Staples (2007: p.4) pointed out that "surface features" such as student-to-student interaction, rather than focusing on students' interaction with mathematical ideas should be encouraged. Similarly, Staples (2014) also pointed out that many reformed-aligned pedagogies do not focus on fostering specific mathematical practices. These insights, supplied by other researchers, further support my assertion that discussion should be framed in terms of mathematical practices rather than quantity or form. A focus on mathematical practices draws attention to how students are interacting with mathematical ideas and helps illuminate the skills required to talk mathematically.

Finally, compared to other studies, this study is broad in its scope. For example, Cobb and Whitenack (1996) noted that they performed extensive analyses on classroom episodes. Such fine-grained studies are certainly important in creating a more nuanced understanding of how norms emerge and affect classroom dynamics. This study, however, illustrates those contextual factors can substantially influence the effectiveness of teacher strategies.

To enhance the effectiveness of teaching and learning, strategies should be dynamic to reflect the dynamic nature of learning (Abdurrahaman, 2010). The findings, that led to new knowledge, in this study suggest that intervention initiatives have resulted in a degree of change at the level of the institution, although there was also some evidence of continuity of existing practices. This can be conceptualised under the broad headings of change (new knowledge) and continuity, as summarised in Table 8.1: Summary of New Knowledge.

Table 8. 1 Summary of New Knowledge

Change (New Knowledge)	Continuity
• Active hands-on engaged activities can focus students' attention on becoming more successful in learning mathematics • Working cooperatively in small groups can support students when they become 'stuck' • Changing embedded practice takes time but with perseverance from the teacher, change can happen • Motivation was important to the students and the teachers needed challenge, control, commitment creation and compassion to enhance their ability to achieve in mathematics	• Teachers' positive engagement with mathematics through a range of strategies help increase the students' understanding and confidence in working with the topic • Giving students an element of choice within a task can help encourage them to work effectively as a team • Teachers' subject knowledge and confidence in the subject should be enhanced as teachers engage more with the subject and experience the progression and development of the subject in all its facets • Through the mathematics interventions teachers will engage as partners in the community and this will affect the students' relationship with the teachers.

8.9 Methodological limitations

The methodology of this study was subject to several limitations. One such limitation stemmed from how I identified norms during Phase One of the study. The study adopted a qualitative approach in the interpretivist epistemological tradition using an action research method. Recall that I identified norms by looking for unelicited student actions. These were any noteworthy actions, either conversational or non-conversational, that students performed without being explicitly prompted by the teachers to do so. While this allowed me to identify noteworthy things that students were doing, it did not allow me to identify noteworthy things that students were not doing. Hence, in Phase One of the study three main themes emerged from the analysis of findings of the data*: motivation, active engagement* and *teacher subject knowledge*. Evidence showed that in terms of *motivation* the teachers' role of maintaining high levels of motivation and the focus of mathematics in the future was discussed. *Active engagement* reflected the nature and scope of active engagement versus textbook lessons, and how different learning styles were instrumental in supporting mathematics in the classroom. *Teacher subject knowledge* indicated that most student participants cited the lack of teacher subject knowledge as a barrier standing in the way of their progress and that they relied on their own personal characteristics to facilitate their learning progress. A particularly intriguing form of intervention involves addressing not the mathematical barriers themselves, but weaknesses in underlying domain-general cognitive abilities. If these interventions could be proven to be successful in addressing both the underlying cognitive deficits and mathematical skills themselves, then they would have wide-reaching impact.

The six intervention lessons from Phase One were outlined and each was planned as a cycle of research that built on each other. The outcome of each intervention lesson gave a focus for the next and the learning objective and the tasks were planned with the aim of meeting the new desired outcome. Each was tailored also to the needs of the group, which included covering the skills and content required for transition from Year Six to Year Seven in secondary school. While some norms were characterised by certain student actions, it is possible that other norms were characterised by an absence of certain student actions. Norms of this type would have been overlooked by my study. For example, Ms. Van Turha mentioned during the semi-structured interviews how she worked to de-emphasise a performance-oriented mentality about mathematics. As part of this, she did not allow her students to frantically wave their hands once they had an answer to one of her questions (inactive participation).

During Phase One when norms were being identified, I did not typically see students frantically waving their hands. While potentially noteworthy, this was not recorded because it reflected an absence of student actions rather than a presence of them. To identify the noteworthy absence of student actions, I believe that a second 'observation lesson' would have been necessary for comparative purposes. This is because there were technically an infinite number of things that students in the observation lesson were not doing. They were not jumping up and down, throwing pencils at each other or screaming loudly. An endless list could be generated. Introducing a second, comparison observation lesson would allow for a more focused examination of noteworthy absences. One could then say that compared to the second lesson observation, the first observation was lacking certain student actions.

Another methodological limitation came from how I defined and thought of norms themselves. I thought of norms as essentially specifying the outcome of a certain set of conditions, that is, if a certain set of conditions arises, then students will respond in the following manner. For example, the norm of *justification* means that if students provide an answer, then they will justify how they obtained it. The norm of computational strategies means that if students mention a multi-digit computation, then they will share how exactly they performed it. Framing norms in this way clarifies what invalidating evidence would look like. Invalidating evidence would mean the presence of the specified conditions without the subsequent expected action. In other words, for justification, this would mean that students share an answer without explaining how they obtained it. The norms of justification and computational strategies are 'explicit' norms. By 'explicit,' I mean that they each had a relatively clear set of conditions under which a certain student action could be expected. These conditions were given earlier in this paragraph. However, 'coherency' was a less explicit norm because it did not have a clear set of corresponding conditions. Students in the study certainly demonstrated evidence of coherency: they would produce generalisations, recognise structural similarities, transfer knowledge from previous problems, and identify equivalencies. However, there was no clear set of conditions under which it would do these things. Similarly, students certainly showed evidence of active engagement: they would use hand signals to indicate agreement with a statement and share their partner's thinking after a pair-share. However, there was no clear set of conditions under which students would do these things either. They did not use hand signals after every statement uttered in the intervention sessions. And they did not necessarily share their partner's thinking after every pair-share. Hence, this means that for coherency, it was not possible to identify invalidating evidence.

A final methodological limitation was the observation schedule: I did not observe the teachers in the study every day and when I did observe, I only observed the class doing mathematics. Since I observed the class on only one occasion for a total of approximately 45 to 50 minutes, it is reasonable to assert that I did not obtain an accurate sense of normal mathematical behaviour. Hence, this assertion does not assume that non-observed days followed the same expectations and patterns of activity as the observed days.

From interviews, I discovered that many of the teacher strategies were not confined to mathematics. Rather, the teachers in the study worked to promote the general ideas of justification and multiple perspectives across their entire mathematics curriculum. In the following interview quote, Mr Tromp (NMT) explains how he worked to promote justification within a lesson as he wants students to take responsibility for their own learning, for example, he would ask the students to tell him why they do certain calculations and then discuss these amongst themselves.

I witnessed some of how Mr Tromp elicited justifications within his observed lesson. When students were correcting answers, they had to justify why a certain answer was appropriate by using the steps in Figure 8.1 below:

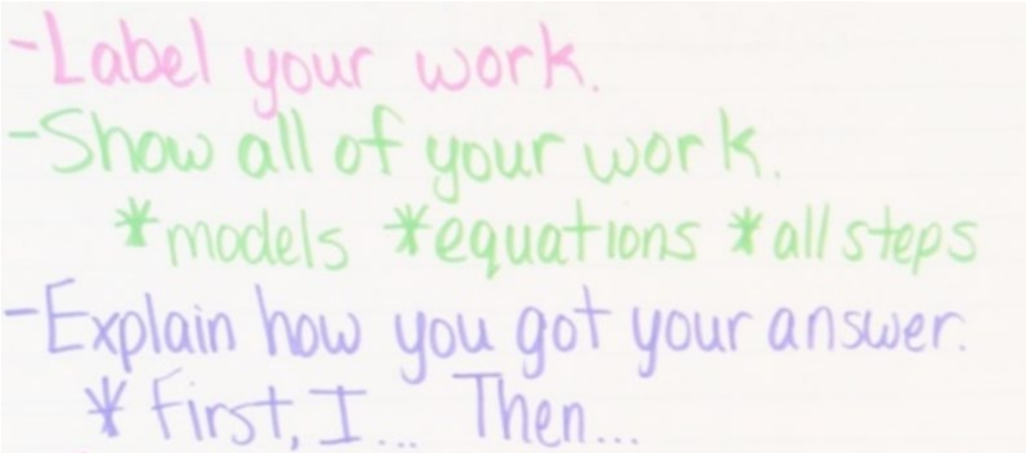


Figure 8. 1 How Students Should Justify Their Answers (Classroom Observation: NMT, June 2013)

The teachers in the study promoted justification, coherency and computational strategies in a range of different ways and it would be unreasonable to conclude that these efforts had no impact on mathematics learning. However, the final intervention with the student participants was the mathematics camp. It focused on supporting the students learning through a camp which was held over a weekend away. Providing a mathematics camp, away from the school, with an educational element and recreational activities was the most sought after, by students, to support an intervention strategy that enhance students' learning. However, due to practical constraints, my report of teacher strategies is limited as Ms Hanekom and I were observers and the teachers at the camp. It is certainly reasonable to speculate that if we had taught other subjects (for example, science or languages) we would have not only worked to establish intended norms during mathematics, but these efforts would also likely have been effective in other subjects we taught.

In summary, the students, at micro level, engaged with the recreational activities and mathematics activities through peer engagement in a different environment supportive of their learning and growth. At meso level, the content-based strategies provided by Ms Hanekom and I supported the students to grow and develop their mathematical thinking and engagement with their peers. The emergence of the *active engagement* theme illustrates that, one of the many ways teachers provide for student access is to adapt rather than change, existing pedagogical provision (exo level) and deliver access through secure subject knowledge for the targeted 'enquiry minds' of the students. Mathematics curriculum quality and integrity at the camp were upheld as the students are subject to cooperative engaged review from their peers.

8.10 Chapter Conclusion

In light of the ongoing interest in student underachievement in secondary school mathematics it was theorised that intervention is a response to a school wide concern and is one of the many strategies that compel a whole school approach. Intervention contributes to progressing student achievement in secondary schools and teacher awareness of mathematics learning at GCSE.

A set of norms connected with mathematically discussions were identified, as well as teacher strategies that support these norms. These teacher strategies encompassed both smaller and day-to-day actions. Given the structure of Key Stages, GCSE curriculum and examination *and* the homogenous preparation of teachers for the teaching of mathematics in England, I propose that such identified norms could be seen across the sector.

Many of the strategies, however, require a certain depth of mathematical content knowledge on the teacher's behalf and will remain inaccessible to teachers lacking this qualification. The results imply that teachers and researchers alike should consider teacher strategies on both a day-to-day scale as well as on a long-term scale. For example, there is an imperative to implement instructional strategies that support motivation, competence, and self-directed learning. Curriculum, teaching, and assessment strategies feature well-scaffolded instruction and ongoing formative assessment that support conceptual understanding, take students' prior knowledge and experiences into account, and provide the right amount of challenge and support on relevant and engaging learning tasks. They also imply that high-level mathematical tasks may take the form of shorter activities, and that a teacher's goals for their tasks may vary depending on content knowledge as they are looking at normative behaviour. Lastly, the results imply that the way we choose to conceptually frame issues like mathematical discussion, whether done consciously or unconsciously, shapes the problems that students perceive and the solutions that they will attempt.

Across the five research questions in this study, several common threads emerged relating to change and continuity, of pressure and inconsistency and of an interaction between intervention and support. Although much technology and many aspects of everyday life, such as, industry, commerce, management and government are mathematics-based, the maintenance and improvement of mathematics education at all levels is vital for the future well-being of the citizens of England. This study has made a contribution to greater understanding of how secondary school mathematics intervention to improve student performance can operate within the limitations of change and continuity within the area of GCSE.

The findings in this study seek to contribute to understanding and knowledge about how interventions can be enacted, with a particular group of students with specific needs, in order to demonstrate the viability of alternative provision to the current models beings used. Nevertheless, these findings show that there is no single most effective solution for mathematics interventions; an opinion shared by Dowker (2009) and Ofsted (2009). Perhaps practices in teaching need to change to make less need for interventions (Cassidy, 2014) or perhaps intervention needs to start sooner to make up the gap between targeted and achieved grades (Welsh Government, 2012). Answering the overarching research problem provides a portrait of some of the on-going change in, and conversations about, the purpose and role of GCSE mathematics interventions in secondary school and can also been part of wider education concerns.

This study showed that students found mathematics a monotonous and challenging subject. They felt mathematics is not useful to their life. Students' attitudes toward mathematics are affected by teaching-learning strategies, teacher personality, and school environment. Teachers' teaching strategy, behaviour of teachers, attitudes of the teacher towards students, perceptions of students and teachers towards mathematics are the factors leading to negative attitudes towards mathematics. However, one of the study's unique characteristics was the continual engagement of the students throughout the five years. Their enthusiasm for developing greater competence and confidence in mathematics was evident in their preparedness to stay with the study and its phases for its entirety.

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APPENDICES:

APPENDIX A: TEACHER/STUDENT INFORMATION SHEET

St Mary's
University College
Twickenham
London

Mr Marc L. Jacobs

Majac Secondary School

Email: 090565@live.stmarys.ac.uk

Ph: 020xxxxxxx

Section A: The Research Project

<u>Title of the project:</u> Given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?

<u>Purpose and value of study</u>: The study seeks to investigate factors that determine why a group of young people, who have performed well in mathematics up to Key Stage 3 (KS 3), then disengage or under-perform at Key Stage (KS 4). I will use action research to facilitate aspects of assessing and reflecting on effectiveness of existing practice, with the view of improving practice. Bassey (1998) describes action research as an enquiry which is carried out to understand, to evaluate and then to change, in order to improve educational practice. Hopkins (2002) maintains that action research combines a substantive act with a research procedure; it is action disciplined by enquiry, a personal attempt at understanding while engaged in a process of improvement and reform. Hargreaves (1996) points out that research-based practice would be more effective and satisfying for practitioners. The value of action research is all about developing the act of knowing through observation, listening, analysing, questioning and being involved in constructing one's own knowledge. The new knowledge and experiences inform the researcher's future direction and influences action.

<u>Invitation to participate:</u> Pupils in Year Seven at Majac Secondary School

will be invited to participate.

<u>Research organiser:</u> Mr Marc Leslie Jacobs is the lead researcher for the project.

Results of the study: Results of the study will be published as soon as they are analysed in national and international journals. The results will also be shared with my current school and it will inform how the school can successfully intervene in mathematics.

Source funding: I will be providing funding for the research.

Contact for further information: See above

Section B: Your Participation in the Research Project

Your invitation: You have been invited to participate in the project that will occur in October / November 2013.

You will be asked to complete a questionnaire, take part in a focus group and a semi-structured interview. The questionnaire will involve well-structured questions based around what you know about mathematics; elicit your feelings, beliefs, experiences, perceptions, and attitudes of mathematics. In the focus group I will observe the range of behaviours of the group and facilitate the discussion, I will also focus on probing you with follow-up questions, as well as ensuring all the participants are given the opportunity to voice their comments. The discussion will be audio recorded and notes will be taken. Each task will take approximately 15-20 minutes and will be held on separate days.

Whether you can refuse to take part: Your participation in the study is completely voluntary. You can choose not to answer any question you do not want to and may decide to discontinue participation at any time. If at any time you wish to withdraw from this study, you are free to do so and need only tell me or state so in writing.

Risks: Although there is no anticipated risk from participating in this study, risk is never completely foreseeable. You can be assured that every precaution has been taken to prevent risk to you.

Withdrawal: To withdraw please complete the tear-off section of your consent form and return to the address above.

Benefits of participation: There is no monetary recompense for participating in this project. The benefits of participating in educational research usually involve an acknowledgement of contributing to the development of greater knowledge of pedagogical practice. The results of the project will be invaluable in helping to inform teaching and learning particularly when children are trying to solve problems.

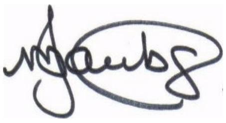
Confidentiality: The information that you make available to the study will be handled confidentially. All identifying names and characteristics will either be changed or withheld, to protect your anonymity. In addition, I will not share notes with anyone except the members of my university, who will abide by the same high standards for confidentiality. I request your permission to use the conclusions for future research publications, conferences, and presentations.

Information collected: The information being collected will be analysed to provide information about how learners solve problems and what teachers can do to ensure that difficulties are addressed. Once analysed the data will be prepared for publication in national and international academic journals. If you participate you will be provided with a pseudonym that ensures your anonymity.

All hard copy data collected will be kept in a locked filing cabinet in the researcher's office. All electronic data, including video image and voice recordings collected will be kept on a computer hard drive and back up drive that are both passwords protected.

This letter should be retained, and you will be given a copy of your consent form. Thank you for your participation in this project.

Yours faithfully



Mr Marc L Jacobs

APPENDIX B: TEACHER CONSENT FORM

St Mary's
University College
Twickenham
London

Teacher Interview: Informed Consent Agreement

Please read this consent agreement carefully before you decide to participate in the study.

Research Title: Given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?

Primary Investigator: Mr Marc L Jacobs

Faculty Supervisor: Dr. Christine Edward-Leis

Purpose of the Research Study: The study seeks to investigate factors that determine why a group of young people, who have performed well in mathematics up to Key Stage 3 (KS 3), then disengage or under-perform at Key Stage (KS 4). I will use action research to facilitate aspects of assessing and reflecting on effectiveness of existing practice, with the view of improving practice. Bassey (1998) describes action research as an enquiry which is carried out to understand, to evaluate and then to change, to improve educational practice. Hopkins (2002) maintains that action research combines a substantive act with a research procedure; it is action disciplined by enquiry, a personal attempt at understanding while engaged in a process of improvement and reform. Hargreaves (1996) points out that research-based practice would be more effective and satisfying for practitioners. The value of action research is all about developing the act of knowing through observation, listening, analysing, questioning and being involved in constructing one's own knowledge. The new knowledge and experiences inform the researcher's future direction and influences action.

What will you do: You will participate in one guided interview? As a participant in the interview, you will discuss what you believe motivates students to learn. With your permission, I will audio tape the interview for the purposes of accuracy. Audio taped interviews will be transcribed and provide me with source material for a close analysis of information. You will have the opportunity to review and revise the transcript. After the study, the audio tapes and field notes will be kept in a box in a locked office and destroyed after five years. If you withdraw from the study, I will erase the tapes and destroy the field notes.

Time Required: A total of about an hour is required for the study: one 30-45-minute interview, and a separate 15-20-minute follow-up discussion. From beginning to end, your participation will last no longer than 4-6 weeks. The discussion session provides an opportunity for you to respond to my interpretations of the interview with you.

Risks: Although there is no anticipated risk from participating in this study, risk is never completely foreseeable. You can be assured that every precaution has been taken to prevent risk to you.

Benefits: Your participation in this study will benefit the existing knowledge base surrounding working with all students. Eventually, studies like this one may lead to improved teaching practices and student engagement. Otherwise, there is no other direct benefit to you.

Confidentiality: The information that you make available to the study will be handled confidentially. All identifying names and characteristics will either be changed or withheld, to protect your anonymity. In addition, I will not share field notes with anyone except the members of my dissertation committee, who will abide by the same high standards for confidentiality. I request your permission to use the conclusions for future research publications, conferences, and presentations.

Voluntary participation: Your participation in the study is completely voluntary. You can choose not to answer any question you do not want to and may decide to discontinue participation at any time. If at any time you wish to withdraw from this study, you are free to do so and need only tell me or state so in writing.

Who to contact if you have questions about the study: Marc L Jacobs, Tel. 07xxxxxx

AGREEMENT: I agree to participate in the research study described above.

Signature of participant: ____

Date: ___________

Signature of Researcher: ____________________________

Date: ___________

You will receive a copy of this form for your records.

APPENDIX C: SAMPLE LESSON OBSERVATION FEEDBACK FORM

LESSON OBSERVATION FEEDBACK

Teacher:		Institution:	Majac Secondary School
Observer:		Year Group:	
Subject:		Date of Lesson:	

The following were viewed:

Individual lesson plan	☐	Curriculum planning	☐	Student assessment records	☐

Brief statement of lesson objectives:

Planning:

Relationship with students:

Organization and delivery of the learning:

Monitoring of student progress

Preparation and use of resources:

Teaching and learning target:

Summary:

Recommandations :

Suggestions:

Grading :	☐	**Excellent**	☐	**Good**	☐	**Development required**	☐	**Unsatisfactory**

Observer's Signature: ……………………………. **Date:** …………………………

Grade Descriptors

Excellent

Students make significant observable progress and show very positive and engaged attitudes to their work, because of highly effective teaching. The teacher's superior knowledge of the subject inspires confidence in the students. Students are highly motivated and work independently where appropriate. Classroom management is highly effective. Based upon thorough and accurate assessment that informs students how to improve, the teacher differentiates work to meet the full range of students' needs. The level of instruction challenges all students. In addition, students have opportunities to assess their own or peers' work where appropriate, which informs further learning. Resources are used with full effectiveness.

Good

Students make measurable progress and show positive attitudes to their work, as a result of effective teaching. The teacher's subject knowledge lends confidence to the teaching style, which engages students and encourages them to work well and independently where possible. Any unsatisfactory behaviour is managed effectively. The level of challenge stretches students without inhibiting. Based upon thorough and accurate assessment that informs students how to improve, work is closely tailored to the full range of students' needs. Students are guided to assess their work themselves where possible. Resources are well deployed.

Development required

Some students make progress, but others show uncooperative attitudes towards their work. Some students are off task, and this is not fully addressed. Teacher's knowledge of the curriculum and the course requirements are satisfactory, but the level of challenge is not always correctly pitched. The methods used do not always sufficiently engage and encourage students. Some independent learning takes place; however, some students remain passive. Formative assessment is infrequent, so teachers do not have a clear enough understanding of students' needs. Some students do not know how to improve. Resources are not fully utilised to support learning where applicable.

Unsatisfactory

Students generally do not make measurable progress and show uncooperative attitudes towards their work. Students are often off task. Teacher's knowledge of the curriculum and the course requirements are incomplete, and the level of challenge is inappropriate for most students. The teaching methods used do not sufficiently engage and encourage students. Not enough independent learning takes place or students are excessively passive. Challenging behaviour is not adequately managed. Formative assessment is minimal, so teachers do not have a clear understanding of students' needs. Students do not know how to improve. Resources are inadequately utilised to support learning.

APPENDIX D: STUDENT CONSENT FORM

St Mary's
University College
Twickenham
London

Student Consent to Participate in Research

My name is Marc Jacobs, and I am conducting research to investigate factors that determine why a group of young people, who have performed well in mathematics up to Key Stage 3 (KS 3), then disengage or under-perform at Key Stage 4 (KS 4) at Majac Secondary School.

I am especially interested in underachieving students, that is, students who are bright, but do not do well in school, or for who school does not seem to work. I hope this study will help lead to ways teachers can make learning more interesting and meaningful to you.

If you decide to participate, you will complete a questionnaire, take part in a focus group and I will interview you once. The interview will take about 30 – 40 minutes. I will ask you questions about what you think motivates you to learn and under what conditions you think you learn well.

The information I collect will be completely confidential; I will not use your name or any information which would give away your identity. Your participation is completely voluntary. You can decide not to participate, even though your parents have already given permission, or even if you change your mind after we start the research project. You can also decide not to answer any question you do not want to.

If you have any questions at any point in the project, you can call me (0208xxxxx) school, if you need to) or e-mail me 090565@live.stmarys.ac.uk).

Below are more complete information about this research project:

Project Title: Given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?

Primary Investigator: Marc L Jacobs

Purpose of the Research Study: The purpose of this study is to better understand what underachieving students believe are the educational conditions and instructional strategies under-which they best, learn Mathematics.

It is hoped that by learning your perspective, teachers will adapt existing strategies and develop new ways to make learning more interesting and meaningful to you. This study is being conducted by Marc L Jacobs.

What will you do: You will participate in a guided interview. As a participant in the interview, you will discuss what you believe motivates you to learn and how you learn well in English and mathematics. With your permission, I will make notes as the interview is in progress.

You will have the opportunity to read through the notes and review / amend it.

After the study, notes will be kept in a box in a locked office and destroyed after five years. If you withdraw from the study, I will destroy the notes.

Time Required: A total of about 45 mins is required for the study and a separate 15-20-minute follow-up discussion. From beginning to end, your participation will last no longer than 2-3 weeks. The discussion session provides an opportunity for you to respond to my interpretations of the interview with you.

Risks: Although there is no anticipated risk from participating in this study, risk is never completely foreseeable. You can be assured that every precaution has been taken to prevent risk to you.

Benefits: Your participation in this study will benefit the existing knowledge base surrounding working with all learners. Eventually, studies like this one may lead to improved teaching practices and student engagement. Otherwise, there is no other direct benefit to you.

Confidentiality: The information that you make available to the study will be handled confidentially. All identifying names and characteristics will either be changed or withheld, to protect your anonymity. In addition, I will not share notes with anyone except the members of my university, who will abide by the same high standards for confidentiality. I request your permission to use the conclusions for future research publications, conferences, and presentations.

Voluntary participation: Your participation in the study is completely voluntary. You can choose not to answer any question you do not want to and may decide to discontinue participation at any time. If at any time you wish to withdraw from this study, you are free to do so and need only tell me or state so in writing.

Who to contact if you have questions about the study: Marc Jacobs, Majac Secondary School

Section B: Your Participation in the Research Project

1. Why you have been invited to take part?

2. Whether you can refuse to take part?

3. Whether you can withdraw from the project at any time, and how?
4. What will happen if you agree to take part? (brief description of procedures/tests)
5. Whether there are any risks involved (e.g. side effects) and if so, what will be done to ensure your wellbeing/safety?
6. Agreement to participate in this research should not compromise your legal rights if something goes wrong.
7. Whether there are any special precautions you must take before, during or after taking part in the study.
8. What will happen to any information/data/samples that are collected from you
9. Whether there are any benefits from taking part
10. How much time you will need to give up taking part in the project
11. How your participation in the project will be kept confidential

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

APPENDIX E: STUDENT FOCUS GROUP INTERVIEW QUESTIONS

Student Focus Group Interview Questions

1. Think of a good learning experience. It can be in school or out of school but think of a time when you had an 'ah-ha!' or when everything fell into place. Maybe you could finally do something you had been struggling with or something finally made sense.

Maybe it was your English teacher who finally taught you how to write a good essay, or maybe it was when your grandfather taught you how to fly fish. So, whether it was in school or out, think of a time that you had a really good learning experience. Briefly describe that experience to me.

2. Now think about what made that a good learning experience. What are the characteristics of your good learning experience?

3. How many of your classes/teachers (include the elements from question 2)? Describe them a little.

4. Describe a good class or teacher that you have now or have had in the past. What made them good?

5. How many of your classes/teachers are like that? Describe them.

6. Help me out. Imagine that the Department of Education came to you and asked to design how Maths should be taught so that you could really learn well, what would you tell them?

7. What is the one thing you would change about how your classes or how your teachers teach which would help you to learn better?

8. How do your teachers help you to successfully learn new material and help you to feel like you can do the work?

9. What do you want to do when you leave school?

10. How is school preparing you for that?

11. How is school preparing you for your future?

12. How do your teachers try to make school interesting to you?

APPENDIX F: ETHICAL APPROVAL

St Mary's
University College
Twickenham
London

St Mary's University College

ETHICS SUB-COMMITTEE

APPLICATION FOR ETHICAL APPROVAL

This form **must** be completed by the researcher for all undergraduate, postgraduate and staff who are either undertaking research as part of a St Mary's Programme of study or an external programme and whose research proposals involve contact with, observation of, or collection and storage of confidential information or data about human participants.

Undergraduate and postgraduate students should have the form signed by their supervisor. For undergraduate students, the supervisor acts as the primary investigator.

For staff research proposals the form should be forwarded to the School representative of the Ethics Sub-Committee for signature.

If, for research projects (staff, undergraduate or postgraduate), the proposal is being submitted for approval to a properly constituted ethics committee external to the University College (e.g. NHS Ethics LREC), please submit a copy of the application and letter approving this application to the Secretary of the Ethics Sub-Committee. External ethical approval may not apply to research/ work carried out in the University College and the Secretary will advise if further action is required.

Before completing this form, please refer to the University College's ethical standards for research and any relevant professional guidelines. As the researcher/ supervisor, you are responsible for exercising appropriate professional judgement in this review.

Please refer to the '*Guidelines for completing the Application for Ethical Approval*' when completing this form. All Ethics Application forms must be submitted and signed, including supervisor signatures where required. If appropriate, your supervisor will refer your application to the School Ethics Sub-Committee representative for Level 2 or Level 3 consideration. For Level 2 consideration, the form will be approved and sign by the School Ethics Sub-Committee representative. For Level 3 consideration, this form should be signed and submitted in hard copy to the Secretary to the University College Ethics Sub-Committee, at least **two weeks** prior to the meeting at which it is being considered. The submission dates, all forms and guidance notes on the intranet:
http://simmspace/about/academic-board/ethics-committee/Pages/default.aspx

Please note: In line with University College Academic Regulations, the signed completed Ethics form must be included as an appendix to the final research project.

If you have any queries when completing this document, please consult your School's Ethics Sub-Committee representative.
Ethics Sub-Committee
Updated August 2012

Please ensure that this section is completed, signed and submitted with the application form

St Mary's RESC Application Checklist

Office Use Only
Ref No:
Date rec'd:
New submission / Re-submission

Name of applicant: Marc Jacobs Name of supervisor: Christine Edwards-Leis
Programme of study: Doctor of Philosophy
Title of Study: Intervention in Mathematics: Creating successful strategies to ensure success in Secondary schools.

The checklist below helps you to ensure that you have all the supporting documents submitted with your ethics application form. This information is necessary for the committee to be able to review and approve your application. Please complete the relevant boxes indicating whether a document is enclosed and where appropriate identifying the version number allocated to the specific document *(in the header/footer)*. Additional documents can be recorded in the boxes provided or extra boxes added to the list if necessary.

	Enclosed? (delete as appropriate)		Version No	Office Use Only
Document	Yes	Not applicable		
Application Form	Mandatory		Yes	
Risk Assessment Form	Yes	N/A	N/A	
Participant Invitation Letter	Yes	N/A	Yes	
Participant Information Sheet	Mandatory		Yes	
Participant Consent Form	Mandatory		Yes	
Parental Consent Form	Yes	N/A	Yes	
Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails	Yes	N/A	N/A	
Letter from host organisation (granting permission to conduct the study on the premises)	Yes	N/A		
Research instrument, eg. validated questionnaire, survey, interview	Yes	N/A	Yes	

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Are you working with persons under 18 years of age or vulnerable adults?	YES
12. Identifiable risks	
a) Is there significant potential for physical or psychological discomfort, harm, stress or burden to participants?	NO
b) Are participants over 65 years of age?	NO
c) Do participants have limited ability to give voluntary consent, including cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment?	NO
d) Is any invasive technique involved, or the collection of body fluids or tissue?	NO
e) Is an extensive degree of exercise or physical exertion involved?	NO
f) Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	NO
g) Are drugs, including liquid and food additives or other substances to be administered?	NO
h) Will deception of participants be used of a nature which might cause distress or which might reasonably affect their willingness to participate in the research? Eg. misleading participants on the purpose of the research by giving them false information	NO
i) Will highly personal, intimate or other private or confidential information be sought? Eg sexual preference	NO
j) Will payment be made to participants including to cover expenses or time involved?	NO If yes, please provide details
k) Is the relationship between the researcher/ supervisor and the participant such that participants might feel pressurised to take part?	NO

Please note it is still incumbent on you to observe the University College's Ethical Guidelines on the conduct of your research, and in particular to ensure that your research complies with the Data Protection Act by which you are legally bound.

If you have any queries in relation to the above, please always discuss this with your Supervisor and your School representative on the Ethics Sub-Committee (for staff applicants), in the first instance.

13. Proposed start and completion date Please indicate when the study is due to commence, timetable for data collection and expected date of completion Please ensure that your start date is at least 2 weeks after the submission deadline for the Ethics Sub-Committee meeting.
Start Date : 18th November 2013 Collecting of Data: Questionnaires – Wk beg. 18th November 2013 Interviews – Wk. beg. 02nd December 2013

Focus group – Wk beg. 02nd December 2013
Lesson Observations – Wk beg. 09th December 2013
End Date for Collecting data : 20th December 2013

14. Sponsors/Collaborators
Please give names and details of sponsors or collaborators on the project. This does not include you supervisor(s).

15. Other Research Ethics Committee Approval
Please indicate whether other approval is required or has been obtained (e.g. NHS, etc) and whether approval has previously been given for any element of this research by the University College Ethics Sub-Committee. Please provide details, as appropriate

N/A

16. Purpose of the study

Provide brief but relevant background and rationale for your study. Be clear about the concepts/factors/performances you will measure/assess/observe and (if applicable), the context within which this will be done. Please state if there is likely to be any direct benefits, eg. to participants, other groups, organisation, if applicable.

My school is larger than the average secondary school and situated in South West London. Two thirds of the school population are boys. The majority of pupils are of White British origin but an increasing and above average, number come from other backgrounds. The school works as a specialist visual arts college. The idea for studying this particular issue came about from a concern within the Senior Leadership Team (SLT), that the General Certificate of Secondary Education (GCSE) mathematics pupils are underachieving, by looking at the past and current Raise Online Data (this data provides interactive analysis of school and pupil performance) and Family Fisher Trust (FFT) D data (Fischer Family Trust is an independent charity that supports projects in health and education, such as FFT Live). The information compiled from the reports (from 2007 – present) and pupil performances in the GCSE Examinations, showed underachievement in mathematics.
This study seeks to investigate factors that determine why a group of young people, who have performed well in mathematics up to Key Stage 3 (KS3), then disengage or under-perform at Key Stage 4 (KS4). I will use action research to facilitate aspects of assessing and reflecting on effectiveness of existing practice, with the view of improving practice. Bassey (1998) describes action research as an enquiry which is carried out in order to understand, to evaluate and then to change, in order to improve educational practice. Hopkins (2002) maintains that action research combines a substantive act with a research procedure; it is action disciplined by enquiry, a

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personal attempt at understanding while engaged in a process of improvement and reform. Hargreaves (1996) points out that research-based practice would be more effective and satisfying for practitioners. My own belief is that carrying out action research is all about developing the act of knowing through observation, listening, analysing, questioning and being involved in constructing one's own knowledge. The new knowledge and experiences inform the researcher's future direction and influences action.
17. Study Design/Methodology Please provide details of the design of the study (qualitative/quantitative etc) and the proposed methods of data collection (exactly what you will do and how; nature of tests, questionnaires, type of interview, ethnographic observation etc) including what will be required of the participants, the extent of their commitment and the length of time they will be required to attend for testing. Please also include details of where the testing will take place. Please state whether the materials/procedures you are using are original or the intellectual property of a third party. If the materials/procedures are original, please describe any pre-testing you have done or will do to ensure that they are effective. **Copies of questionnaires to be used and/or interview schedules should be attached to this application.**

Quantitative researchers use numbers and large samples to test theories, and qualitative researchers use words and meanings in smaller samples to build theories (Easterby-Smith et al., 1991). The chosen paradigm for my research will be qualitative research. Researchers working in the social sciences such as psychology, sociology, anthropology, and etcetera use this research method. They are interested in studying human behaviour and the social world inhabited by human beings (Morgan, 1983). Gomm (2004:7) and Merriam (1998:5) state that qualitative researchers are primarily interested in how people experience the world and or how they make sense of it. My intention is to ascertain how pupils as participants perceive their world of secondary mathematics. I will use an interpretive approach in order to probe the participants' experiences and perceptions of their participation in mathematics.
This approach is supported by Cohen, Manion & Morrison (2000:19) who argue that, "interpretive research, individual behaviour can be understood by the researcher sharing their frame of reference: understanding of individuals' interpretations of the world around them has to come from inside, not the outside" .Furthermore, Kaplan and Maxwell (1994:4) argue that interpretive research methods are intended to help researchers understand people and the social and cultural contexts within which they live. Choosing to analyse textual data for meaning making, for example, is best done qualitatively. Making clear the definition of meaning, making choices about how to partition the data or select from it, and so on, is all about using qualitative methods. I will consider this when I interview pupils and staff at my current school in order to shed light on the issue at hand. The pupils and staff will have different contexts and different experiences, which will enable me as the researcher to get a sense of the unique social and cultural contexts of each.

I will interview different role players (teachers, Head of Key Stage, Transition Coordinator) at the school who interacts with the pupils in order to get a holistic view of the nature of the pupils' participation in mathematics. With reference to this approach Miles and Huberman (1994:6-7) are of the opinion that the role of the researcher is to gain a holistic overview of the context in which the said organisation operates. Goetz and Le Compte (1984) support this with their argument that qualitative research is holistic, in the sense that it attempts to provide an appropriate understanding of the complex interrelationships of causes and consequences that effect human behaviour. Based on these thoughts of the different qualitative commentators and practitioners, I hope to find the characteristics of this approach very appropriate for this study. A research design is described by Mouton (2001:114) as the…" design and methodology which follows in your study in order to investigate the problem as formulated".
Data collection will involve qualitative methods such as: focus groups, semi structured interviews, intervention (Action Research: 5 teachers in my school), classroom observations and likert scale questionnaires conducted during the last six weeks of the autumn term 2013 at Teddington school. To help support and validate the findings, five teachers will be interviewed and at least 5 hours of classroom observations will be conducted. The data will help me to better understand the context of the pupils' responses and added confidence to my interpretations.

18. Participants
Please describe how many participants will be required to complete the study, their age, sex, how they will be chosen/recruited and inclusion/exclusion criteria. Discuss how participants will be recruited and from where
For internet studies make sure that you clarify how you will verify the age of the participants. Indicate the number of participants you are recruiting and why

19a) Are there any incentives/pressures which may make it difficult for participants to refuse to take part (i.e. will coercion be used in the recruitment of participants)?
If so, explain and clarify why this needs to be done

N/A

19b) Will any of the participants be from any of the following groups?
Children under 18 **Yes**
Participants with learning disabilities **No**
Participants suffering from dementia **No**
Other vulnerable groups. If any of the above apply, does the researcher/investigator hold a current CRB disclosure? A copy of the CRB must be included with the application.

Yes. I do hold a current CRB include CRB number

19c) How will consent be obtained?
This includes consent from all necessary persons (e.g. participants and parents)

Research should, as far as possible, be based on participants' freely volunteered informed consent. This implies a responsibility to explain fully and meaningfully what the research is about and how it will be disseminated. Participants should be aware of their right to refuse to participate; understand the extent to which confidentiality will be maintained; be aware of the potential uses to which the data might be put; and in some cases be reminded of their right to re-negotiate consent. Corti, L. (2000).
However, the issue as to what extent participants can ever be fully informed is a much disputed one. Explaining the details of a research project and the intentions of the study intentions requires is a prerequisite before entering into fieldwork, but we should never assume that all participants have a detailed appreciation of the nature and aims of academic research. Finally, consent alone does not absolve the responsibility of researchers to anticipate and guard against potential harmful consequences for participants. Rock, F.E. (1999).

Participants:
Pupils: An invitation letter will be send to all pupils, their parents /carers to seek their consent in this study.
Teachers: An invitation letter will be send to all teachers to seek their consent in this study.

20. Risks and benefits of research/ activity

20a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle, participant burden) associated with this study? If so please provide details including information on how they will be minimised.

N/A

Please explain where the risks/effects may arise from (and why), such that it is clear why the risks /effects will be difficult to completely eliminate or minimise.

N/A

20b) Does the study involve any invasive procedures? If so, please confirm that the researchers or collaborators have appropriate training and are competent to deliver these procedures.

Invasive procedures also include the use of deceptive procedures in order to obtain information.

N/A

20c) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting?

No

Please clarify why this information is necessary (and if applicable, any prior use of the questionnaire/interview).

N/A

20d) Please describe how you would deal with any adverse reactions participants might experience.

Discuss any adverse reaction that might occur and the actions that will be taken in response to this by you, your supervisor or some third party (explain why a third party is being use for this purpose).

N/A

20e) Are there any potential benefits of participating in the research to the participants (e.g. gaining a knowledge of their fitness, finding out personality type, improving performance etc)?

There is no monetary recompense for participating in this project.The benefits of participating in educational research usually involve an acknowledgement of contributing to the development of greater knowledge of pedagogical practice. The results of the project will be invaluable in helping to inform teaching and learning particularly when children are trying to solve problems.

The focus is on direct benefits to the participants/organisation/institution/school involved in the study that they will be directly or indirectly made aware of by you. If you intend to provide feedback to organisations etc, please explain what form this will take.

Results of the study will be published as soon as they are analysed in national and international journals. The results will also be shared with my current school through a meeting with the head teacher and senior leadership team (SLT) to inform them how the school can successfully intervene in mathematics. I will request participants' permission to use the conclusions for future research publications, conferences, and presentations.

21. Confidentiality, privacy and data protection

21a) What steps will be taken to ensure participant's confidentiality?

Describe how data, particularly personal information, will be stored. Also consider how you will identify participants who request their data be withdrawn, after you have collected it, such that you can do this but maintain the confidentiality of theirs and others data.

Researchers use secure procedures for all computer-based storage of Protected Information including servers, laptops, handheld computers, and any other type of data storage device. Security procedures (e.g., encryption, password protection) should be standard practice whenever conducting research using databases that include identifiers. Research participants must be given fair, clear, honest explanations of what will be done with information that has been gathered about them and the extent to which confidentiality of records will be maintained. However, the promise of confidentiality cannot be absolute. Under court order or subpoena for example, there may be legal reasons for compelling a researcher to disclose the identity of, or information about, a research participant. In some instances, a researcher may be mandated to report information to government agencies as in cases of child abuse or elder abuse, certain communicable diseases, illegal drug use, and other situations such as gunshot wounds. Lowrance, (2003)

The information available to this study will be handled confidentially. All identifying names and characteristics will either be changed or withheld, to protect pupil anonymity. In addition, I will not share notes with anyone except the members of my university, who will abide by the same high standards for confidentiality.

21b) Will the data be stored securely?

Explain how and where the data will be stored. All research data must be stored for a minimum of 5 years. For research projects being funded by Research Council UK bodies, their policy on research data must be adhered to.

Extensive data may be stored either as hard copy or on disks. In such cases, carefully documented definitions for codes should be included, together with rules for applying them to the field data and notes. The use of computers in research laboratories is a necessity, and managing the data generated and stored is becoming a challenge to the investigator. As more and more data are generated electronically, current documentation methods involve both the hand-written laboratory notebooks discussed above as well as electronic files pertaining to experiments. Establishing processes to organise, store and protect such electronic data is becoming crucial. One way to manage the generated electronic data is to use electronic lab notebooks. Such notebooks allow the direct entry of laboratory observations, results from data analysis, and the seamless transfer of electronic data and images from a variety of laboratory instruments in a centralized fashion. In addition, background information on reference materials or protocol details can be entered from electronic sources. One advantage of using such a notebook is the ability to secure the data electronically so as to prevent subsequent data manipulations. In addition such systems will also provide the ability to add electronic signatures for further validation. Electronic notebooks can be developed in house or can be purchased from a commercial vendor. In establishing a process to protect the data and ensure that the data are formatted so that they could not be modified, one suggestion would be to write the data to a CD-ROM (CD-R) where they could not be modified or overwritten. Bloodborne Pathogens(1995)

All hard copy data collected will be kept in a locked filing cabinet in the researcher's office. All electronic data, including voice recordings collected will be kept on a computer hard drive and back up drive that are both password protected.

21c) Who will have access to the data?

Please identify all persons who will have access to the data (normally yourself and your supervisor)

It will be me, (Mr Marc Jacobs) and Dr. Christine Edward-Leis

21d) Will the results of the analysis include information which may identify people or places?

If so, explain what information will be identifiable and whether the persons or places (e.g. organisations) are aware of this. This also refers to likely outputs eg. dissertations, theses and any future publications/presentations. If this is the case, this should be included in the Consent form.

N/A

22. Feedback to participants

Please give details of how, if appropriate, feedback will be given to participants.
As a minimum, it would normally be expected for feedback to be offered to participants in an acceptable to format, eg. summary of findings.
Please state whether you intend to provide feedback to any other individual(s) or organisation(s) and what form this would take.

Steneck, (2004) stated that as part of the scientific process, data are expected to be shared and reported.

This serves several purposes, including the following:

- Acknowledging a study's implications
- Contributing to a field of study
- Stimulating new ideas

By sharing research results, a project may advance new techniques and theories and benefit other research. It encourages collaboration between researchers in the same field or across disciplines. Data sharing usually occurs once a study has been completed. Data reporting includes discussion of the data, the data analysis, and the authorship of a project, especially in the context of a particular scientific field. Data sharing and reporting are typically accomplished by publishing results in a scientific journal or establishing a patent on a product.

Before publication, there is often no obligation to share any preliminary data that have been collected. In fact, sharing at this stage is sometimes discouraged because of the following reasons:

- The implications for a set of data may not be understood while a project is still in progress. By waiting until a project is ready for publication, researchers ensure that what they share has been carefully reviewed and considered.
- There is fear that less scrupulous researchers will use shared research results for their own gain. This apprehension causes some researchers to refrain from disseminating their findings (Helly et al., 2002).

Many researchers find it worthwhile to present preliminary findings in a conference setting before the study is complete to inform peers about their forthcoming research.

In my research I will share the data with all participants, if they would like to know the outcome of the research, and with the headteacher, governing body and senior leadership team (SLT) at Teddington school.

The proposer recognises their responsibility in carrying out the project in accordance with the University College's ethical guidelines and procedures and will ensure that any person(s) assisting in the research/ teaching is also bound by these. The Ethics Sub-Committee must be notified of and approve any deviation from the information provided on this form.

Please note that for all Undergraduate research projects, the supervisor is considered to be the Principal Investigator for the study.

Signature of Proposer(s)	Date: 28th October 2013
Signature of Supervisor (for student research projects)	Date: 28/10/13

APPROVAL SHEET
Name of applicant: Marc Jacobs Name of supervisor: Christine Edwards-Leis Programme of study: Doctor of Philosophy Title of Study: Intervention in Mathematics: Creating successful strategies to ensure success in Secondary schools.
ACTION TAKEN
Supervisors, please complete Section 1 OR Section 2 If approved at Level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1
Approved at Level 1 Signature of supervisor (for student applications) C E Edwards-Leis Signature of School Ethics Representative (for staff applications) Date 28/10/13
SECTION 2
Refer to School Ethics Representative for consideration at Level 2 or Level 3 Signature of supervisor C E Edwards-Leis Date 28/10/13
SECTION 3
To be completed by School Ethics Representative Approved at Level 2 Signature of School Ethics Representative Jane Chambers Date 04.11.13

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Updated August 2012

SECTION 4

To be completed by School Ethics Representative

Level 3 assistance required (including all staff research involving human participants)

Signature of School Ethics Representative...

Date...

Level 3 approval – confirmation will be via correspondence from the Ethics Sub-Committee

St Mary's University Twickenham London

St Mary's University

Ethics Sub-Committee

Application for Ethical Approval (Research)

This form must be completed by any undergraduate or postgraduate student, or member of staff at St Mary's University, who is undertaking research involving contact with, or observation of, human participants.

Undergraduate and postgraduate students should have the form signed by their supervisor, and forwarded to the Faculty Ethics Sub-Committee representative. Staff applications should be forwarded directly to the Faculty Ethics Sub-Committee representative. All supporting documents should be merged into one document (in order of the checklist) and named in the following format: '**Full Name – Faculty – Supervisor'**

Please note that for all undergraduate and taught masters research projects the supervisor is considered to be the Principal Investigator for the study.

If the proposal has been submitted for approval to an external, properly constituted ethics committee (e.g. NHS Ethics), then please submit a copy of the application and approval letter to the Secretary of the Ethics Sub-Committee. Please note that you will also be required to complete the St Mary's Application for Ethical Approval.

Before completing this form:

- Please refer to the **University's Ethical Guidelines**. As the researcher/ supervisor, you are responsible for exercising appropriate professional judgment in this review.
- Please refer to the Ethical Application System (Three Tiers) information sheet.
- Please refer to the Frequently Asked Questions (FAQs) and Commonly Made Mistakes sheet.

- If you are conducting research with children or young people, please ensure that you read the **Guidelines for Conducting Research with Children or Young People**, and answer the below questions with reference to the guidelines.

Please note:

In line with University Academic Regulations the signed completed Ethics Form must be included as an appendix to the final research project.

St Mary's University Twickenham London

St Mary's Ethics Application Checklist

The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application. Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be re-submitted at a later date.

Document	**Enclosed?***	**Version No**
1. Application Form	Mandatory	
2. Participant Invitation Letter	☐ Yes ☒ No ☐ Not applicable	
3. Participant Information Sheet(s)	Mandatory	
4. Participant Consent Form(s)	Mandatory	
5. Parental Consent Form	☐ Yes ☒ No ☐ Not applicable	
6. Participant Recruitment Material - e.g. copies of posters, newspaper adverts, emails	☐ Yes ☐ No ☒ Not applicable	

7. Letter from host organisation (granting permission to conduct study on the premises)	☒ Yes ☐ No ☐ Not applicable	
8. Research instrument, e.g. validated questionnaire, survey, interview schedule	☒ Yes ☐ No ☐ Not applicable	
9. DBS certificate available (original to be presented separately from this application)*	☐ Yes ☒ No ☐ Not applicable	
10. Other Research Ethics Committee application (e.g. NHS REC form)	☒ Yes ☐ No ☐ Not applicable	
11. Certificates of training (required if storing human tissue)	☐ Yes ☐ No ☒ Not applicable	

I can confirm that all relevant documents are included in order of the list and in one document (any DBS check to be sent separately) named in the following format:

'Full Name - Faculty – Supervisor'

Signature of Proposer:		Date:	30th June 2020
Signature of Supervisor (for student research projects):		Date:	30th June 2020

Ethics Application Form

1. Name of proposer(s)	Mr Marc Leslie Jacobs
2. St Mary's email address	090565@live.stmarys.ac.uk
3. Name of supervisor	Dr Christine Edwards- Leis
4. Title of project	*Given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?*

5. Faculty or Service	☒ EHSS ☐ SHAS ☐ Institute of Theology
6. Programme	☐ UG ☒ PG (taught) ☐ PG (research) Name of programme: Ph D Philosophy
7. Type of activity	☐ Staff ☐ UG student ☒ PG student ☐ Visiting ☐ Associate

8. Confidentiality	
Will all information remain confidential in line with the Data Protection Act 2018?	☒ Yes ☐ No
9. Consent	

Will written informed consent be obtained from all participants/participants' representatives?	☒ Yes ☐ No ☐ Not applicable
10. Pre-approved Protocol	
Has the protocol been approved by the Ethics Sub-Committee under a generic application?	☒ Yes ☐ No ☐ Not applicable Date of approval:04/07/2013
11. Approval from another Ethics Committee	
a) Will the research require approval by an ethics committee external to St Mary's University?	☐ Yes ☒ No
b) Are you working with persons under 18 years of age or vulnerable adults?	☒ Yes ☐ No

12. Identifiable risks		
a)	Is there significant potential for physical or psychological discomfort, harm, stress or burden to participants?	☐Yes ☒ No
b)	Are participants over 65 years of age?	☐Yes ☒ No
c)	Do participants have limited ability to give voluntary consent? This could include cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment.	☐Yes ☒ No
d)	Are any invasive techniques involved? And/or the collection of body fluids or tissue?	☐Yes ☒ No
e)	Is an extensive degree of exercise or physical exertion involved?	☐Yes ☒ No
f)	Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	☐Yes ☒ No
g)	Are drugs or other substances (including liquid and food additives) to be administered?	☐Yes ☒ No
h)	Will deception of participants be used in a way which might cause distress, or might reasonably affect their willingness	☐Yes ☒ No

	to participate in the research? For example, misleading participants on the purpose of the research, by giving them false information.	
i)	Will highly personal, intimate or other private and confidential information be sought? For example sexual preferences.	☐Yes ☒ No
j)	Will payment be made to participants? This can include costs for expenses or time.	☐Yes ☒ No If yes, provide details:
k)	Could the relationship between the researcher/ supervisor and the participant be such that a participant might feel pressurised to take part?	☐Yes ☒ No
l)	Are you working under the remit of the Human Tissue Act 2004?	☐Yes ☒ No
m)	Do you have an approved risk assessment form relating to this research?	☐Yes ☒ No

13. Proposed start and completion date
Please indicate: • When the study is due to commence. • Timetable for data collection. • The expected date of completion. Please ensure that your start date is at least five weeks after the submission deadline for the Ethics Sub-Committee meeting.
As I have already undertaken this research, I am applying for this retrospectively. Please see table below:

Action	Date
Letters sent to prospective participants (students and teachers)	December 2012
Teacher participants recruited	February 2013
Phase One: Initial Data collection and analysis	
Ten teacher participants recruited	January 2013
Initial focus groups interviews (Year 7 students)	June 2013
Initial semi-structured one-to-one teacher interview	June 2013
Classroom observations	June 2013
Focus group and teacher interviews and data transcribed and analysed	August 2013–April 2014
Six weeks Intervention programme	April–May 2014
Phase Two: Final data collection and analysis	**Date**
Final focus group interviews with students (Year 9)	July 2015
Final semi-structured one-to-one teacher interviews	July 2015
Focus group and teacher interviews and data transcribed and analysed	August – December 2015
Weekend away Intervention (Year 11) 10 student participants)	March 2017

14. Sponsors/collaborators

Please give names and details of sponsors or collaborators on the project. This does not include your supervisor(s) or St Mary's University.

- Sponsor: An individual or organisation who provides financial resources or some other support for a project.
- Collaborator: An individual or organisation who works on the project as a recognised contributor by providing advice, data or another form of support.

n/a

15. Other Research Ethics Committee Approval
Please indicate: • Whether additional approval is required or has already been obtained (e.g. an NHS Research Ethics Committee). • Whether approval has previously been given for any element of this research by the University Ethics Sub-Committee. Please also note which code of practice / professional body you have consulted for your project.
Approval was granted on 04/11/13 by Jane Chambers (Chair)

16. Purpose of the study
In lay language, please provide a brief introduction to the background and rationale for your study. *[100 word limit]*
I am applying for this respectively. I have adopted an action research method which meant that the project evolved after the first round of data collection. I thought that I had sufficient scope with the first approval but realised that I did not include the details regarding the action research. The same student participants (10) were with the study throughout – no changes to student participants but, as one teacher left the school for a promotion job I replaced him with another teacher, who started and replaced him. The new teacher was willing to take part in the research. **Ethics approval form 2013 included / attached**

17. Study design/methodology
In lay language, please provide details of: a) The design of the study (qualitative/quantitative questionnaires etc.) b) The proposed methods of data collection (what you will do, how you will do this and the nature of tests). c) The requirement of the participant i.e. the extent of their commitment and the length of time they will be required to attend testing.

d) Details of where the research/testing will take place, including country.

e) Please state whether the materials/procedures you are using are original, or the intellectual property of a third party. If the materials/procedures are original, please describe any pre-testing you have done or will do to ensure that they are effective.

Ethics approval form 2013 included / attached

The changes in the data collection methods were that I have undertaken two focus group interviews with the students and two sets of semi structured teacher interviews with teacher and one teacher, Mr Tromp left the school and was replaced by Mr Davids. Mr Davids also completed a participant consent form to take part in the research study. The whole cohort of Year 7 students took part in an online questionnaire to which I (as researcher) decided that this quantitative data was not needed for the research as the study mostly used Qualitative data. The students did not take part in any further interviews apart from the two focus groups and providing feedback on the interventions. Also, two sets of interventions were undertaken with the students, i.e. a six week after school programme for the participants and a mathematics camp with the participant students.

Semi structured interview questions (see attached document).

The mathematics staff and the researcher selected the 10 prospective participants for the focus group interviews and put them into two groups (Cohort A and B); and,

Careful planning was required for the focus group interview questions. Initially, designing interview questions that adequately reflected what was required by the research questions was vital (Cohen et al., 2015). While it was necessary to formulate semi-structured focus group questions that were focused on answering the research questions, it was important at the same time not to be too specific (Bryman, 2012). I (as the researcher) would be able to interpret what is relevant in a specific sense rather than seeking to understand and clarify what the participant saw as being relevant. In this way, I could gain insight on what the participant subjectively perceived as being significant in relation to the focus of the research. This process helped in ensuring that the focus group interviews elicited the views and perspectives of the participants, which was important ethically (Polkinghorne, 2005) for the integrity of the research and important in a substantive sense for the contribution to understanding that the data would make. As part of Majac Secondary Schools in-school monitoring and evaluation procedures, groups of students were regularly interviewed to get their views on different aspects of the school. The familiarity of this type of group discussion, as opposed to one-to-one interviews, which are used in school for investigating poor behaviour, make it more likely that the students gave honest responses in this situation. Therefore, two sets of 50-minute formative focus group interviews were convened with two sets of five participants. The semi-structured questions (see attachment) were asked of the participants to which they replied without hesitation. The students were seated around a table, with the supervisor, Dr Christie Edward -Leis (as an observer) and me. This arrangement took advantage of one of the benefits of the group interviews (Morgan and Krueger, 1998) which is their similarity to a normal classroom discussion despite being inevitably artificial. The focus group interviews were semi-structured with guiding questions and prompts but with the flexibility to pursue lines of enquiry stimulated by responses. The purpose of having my supervisor with me was twofold: (a) to validate the information obtained by an independent observer, and (b) to ensure the trustworthiness and credibility of the data. The focus group interviews were conducted in a quiet area, the library of Majac Secondary School, away from the rest of the school and were audio recorded in their entirety. At the end of each interview (semi-structured one-to-one and focus group), the audiotape was transcribed verbatim. When transcribing the interviewees' statements verbatim, it is acceptable to leave out fillers in speech patterns, such *as um ,ah, like, you know*, unless it greatly changes the context of what was stated (Adams, 2011; Jongbloed, 2011; Evers,2011).

The researcher's first supervisor independently undertook coding sample of semi-structured one-to-one teacher interviews and focus group interviews with students. The first supervisor randomly coded items from the interview transcripts. The coding reliability ranged from 92-100% accuracy with an average of 95.8%. Similarly, 12.9 % of the teacher interviews were randomly chosen and coded for five items from the interview transcripts. The coding reliability overall ranged from 87% to 93%.

18. Participants

Please mention:

a) The number of participants you are recruiting and why. For example, because of their specific age or sex.

b) How they will be recruited and chosen.

c) The inclusion/exclusion criteria.

d) For internet studies please clarify how you will verify the age of the participants.

e) If the research is taking place in a school or organisation then please include their written agreement for the research to be undertaken. The former headteacher (Mr Weeks) and former deputy Headteacher, in charge of Teaching and Learning, verbally agreed with me (as researcher) that I can undertake this research study as it followed on from my MA: Innovation and Change, which the school partially funded and also partially funded the PhD until 2015. Evidence of the funding on my payslips.

f) I was a teacher Majac Secondary School from April 2007 to December 2015 when I left the institution to work in Higher Education from January 2016.

For the whole duration of the research study there were no changes to the student participants but only to one of the teachers, as I identified earlier. **Ethics approval form 2013 included / attached**

19. Consent
If you have any exclusion criteria, please ensure that your Consent Form and Participant Information Sheet clearly makes participants aware that their data may or may not be used. a) Are there any incentives/pressures which may make it difficult for participants to refuse to take part? If so, explain and clarify why this needs to be done. b) Will any of the participants be from any of the following groups? ➢ Children under 18 ➢ Participants with learning disabilities ➢ Participants suffering from dementia ➢ Other vulnerable groups. If any of the above apply, state whether the researcher/investigator holds a current DBS certificate (undertaken within the last 3 years). A copy of the DBS must be supplied **separately from** the application. c) Provide details on how consent will be obtained. This includes consent from all necessary persons i.e. participants and parents.
Ethics approval form 2013 included / attached

20. Risks and benefits of research/activity
a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle) associated with this study? If so please provide details, including information on how these will be minimised.

b) Please explain where the risks / effects may arise from (and why), so that it is clear why the risks / effects will be difficult to completely eliminate or minimise.

c) Does the study involve any invasive procedures? If so, please confirm that the researchers or collaborators have appropriate training and are competent to deliver these procedures. Please note that invasive procedures also include the use of deceptive procedures in order to obtain information.

d) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting? If so, please clarify why this information is necessary (and if applicable, any prior use of the questionnaire/interview).

e) Please describe how you would deal with any adverse reactions participants might experience. Discuss any adverse reaction that might occur and the actions that will be taken in response by you, your supervisor or some third party (explain why a third party is being used for this purpose).

f) Are there any benefits to the participant or for the organisation taking part in the research?

The students benefitted from an after-school class as there were only 10 of them and two teachers (Ms Hanekom and me). The small group of students engaged in smaller groups of 3 students where they cooperatively engaged with each other. At the mathematics camp the students were also in small cooperative groups of 3 or 4 and this enhanced their engagement, through discussions and active involvement with each other. Ms Hanekom shadowed me throughout the after-school sessions and also at the camp. She gained valuable knowledge, she increased her skills and understanding of how GCSE mathematics was taught.

Ethics approval form 2013 included / attached

21. Confidentiality, privacy and data protection

- Outline what steps will be taken to ensure participants' confidentiality.
- Describe how data, particularly personal information, will be stored (please state that all electronic data will be stored on St Mary's University servers).
- If there is a possibility of publication, please state that you will keep the data for a period of 10 years.
- Consider how you will identify participants who request their data be withdrawn, such that you can still maintain the confidentiality of theirs and others' data.

- Describe how you will manage data using a data a management plan.
- You should show how you plan to store the data securely and select the data that will be made publically available once the project has ended.
- You should also show how you will take account of the relevant legislation including that relating to data protection, freedom of information and intellectual property.
- Identify all persons who will have access to the data (normally yourself and your supervisor).
- Will the data results include information which may identify people or places?
- Explain what information will be identifiable.
- Whether the persons or places (e.g. organisations) are aware of this.
- Consent forms should state what information will be identifiable and any likely outputs which will use the information e.g. dissertations, theses and any future publications/presentations.

Ethics approval form 2013 included / attached

The research school's name is a pseudonym and no identifying details concerning the school or area was referred to in the study.

22. Feedback to participants

Please give details of how feedback will be given to participants:

- As a minimum, it would normally be expected for feedback to be offered to participants in an acceptable format, e.g. a summary of findings appropriately written.
- Please state whether you intend to provide feedback to any other individual(s) or organisation(s) and what form this would take.

Ethics approval form 2013 included / attached

The proposer recognises their responsibility in carrying out the project in accordance with the University’s Ethical Guidelines and will ensure that any person(s) assisting in the research/ teaching are also bound by these. The Ethics Sub-Committee must be notified of, and approve, any deviation from the information provided on this form.

Name of Proposer:	Marc Jacobs		
Signature of Proposer:		Date:	30/06/2020
Name of Supervisor (for student research projects):	Dr Christine Edwards-Leis		
Signature of Supervisor:		Date:	30/06/2020

St Mary's University Twickenham London

Approval Sheet

(This sheet must be signed at all relevant boxes)

Name of proposer(s)	Mr Marc Leslie Jacobs
Name of supervisor(s)	Dr Christine Edwards- Leis
Programme of study	
Title of project	*Given the nature of secondary schools, why and in what ways do students underachieve and disengage in mathematics and what, if any, has been the impact of interventions on students and teachers?*

Supervisors, please complete section 1. If approved at level 1, please forward a copy of this Approval Sheet to the Faculty Ethics Representative for their records.

SECTION 1: To be completed by supervisor (for student research projects)			
☐ Approved at Level 1. ☒ Refer to Faculty Ethics Representative for consideration at Level 2 or Level 3.			
Name of Supervisor:	Christine Edwards-Leis		
Signature of Supervisor:	C Edwards-Leis	Date:	2nd July 2020

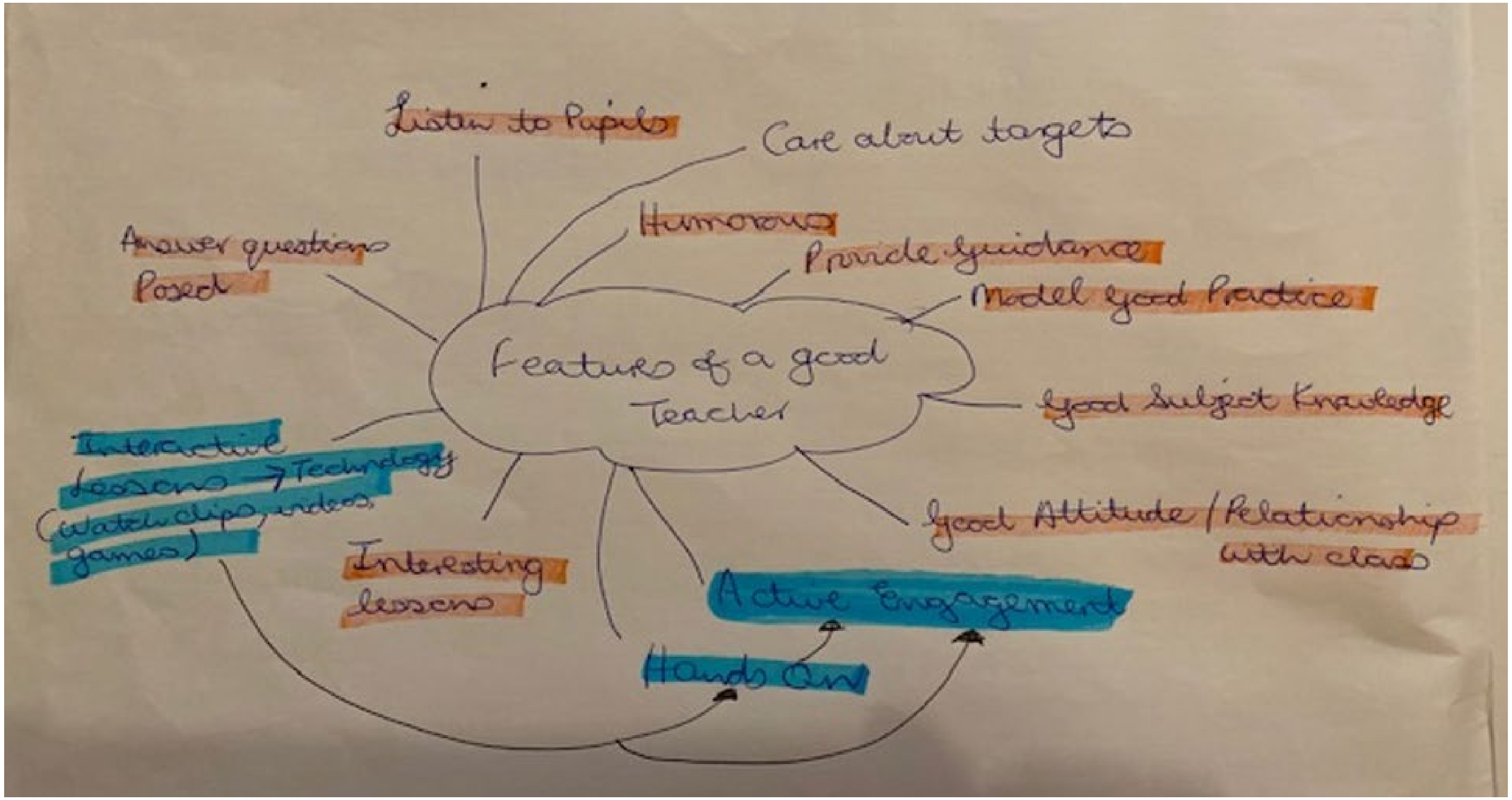
SECTION 2: To be completed by Faculty Ethics Representative.

☒ Approved at Level 2.

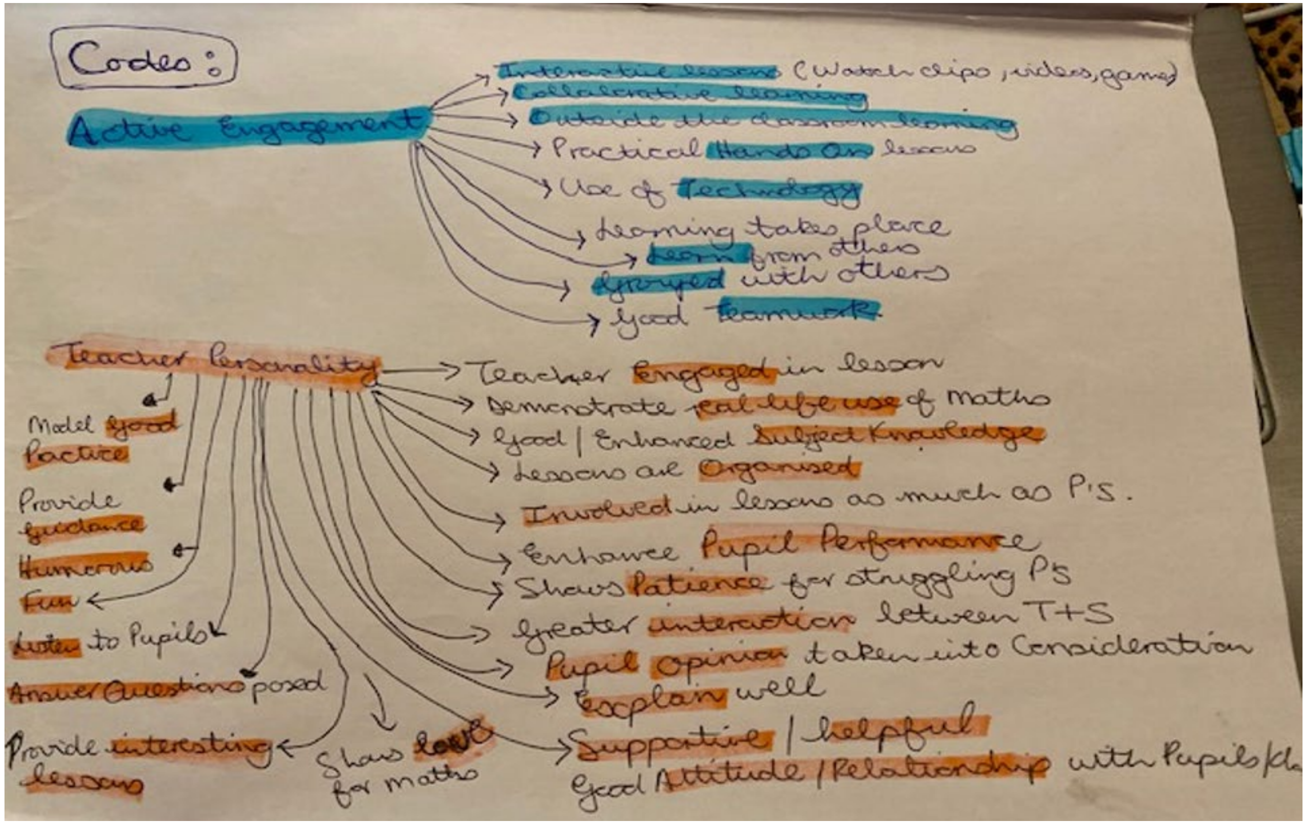
☐ Level 3 consideration is required by Ethics Sub-Committee.

Name of Faculty Ethics Representative:	MATTHEW JAMES		
Signature of Faculty Ethics Representative:		Date:	2nd July 2020

APPENDIX G: CONNECTION BETWEEN THE CODES



APPENDIX H: CODING OF KEY PHRASES



APPENDIX I: TEACHER SEMI-STRUCTURED INTERVIEW QUESTIONS

St Mary's
University College
Twickenham
London

Teacher Interview questions

1). You know I have been observing some of your students. What motivates those students? When do they learn well? What are their interests and goals?

2). Dealing with students who do not seem interested in educational can be a real challenge. What are some of the things you try to do to get through to these students?

3). What makes it hard to reach those students?

4). Think of a good educational experience. It can be in school or out of school but think of a time when you had an ‘ah-ha!’ or when everything fell. into place. Maybe you could finally do something you had been struggling with or something finally made sense

5). Maybe it was your Art teacher who finally taught you how to mix paint to get primary colours, or maybe it was when your mother / dad taught you how to tie your shoelaces. So, whether it was in school or out, think of a time that you had a really good educational experience. Briefly describe that experience to me.

6). Now think about what made that a good educational experience. What are the qualities of your good educational experience?

7). In how many of your classes/ lessons do you include the elements from Question 2? Describe them a little (if any?)

8). How do you help students prepare for their goals for the future?

9). How do you plug into student interests?

10). How do you try to show students than course content is useful and important to them?

11). What kinds of choices do you give students and what kinds of decisions do you let them make?

12). To what extent do you agree with the statement “When it comes right down to it, a teacher really can’t do much because most of a student’s motivation and performance depends on his or her home background”?

13). To what extent do you agree with the statement, “If I really try hard, I can get through to even the most difficult or unmotivated student”?

A SUMMARY OF TEACHER PARTICIPANT INTERVIEW GUIDE AND PLANNED QUESTIONS

Speaker Key

MJ Marc Jacobs

Teacher: XXX

Speaker	**Comments**
MJ	Okay, XXX (teacher name) welcome to this teacher interview and thank giving up your time to attend this interview. This is XXX and she also teaches year 7 mathematics. A teacher in her XXX year. Right, so, you know that I have been observing some of the students in your lessons. What do you think motivates students to learn
MJ	Okay. So, when do you think they learn well?
MJ	Okay, thank you. So, dealing with students who do not seem interested in education can be a real challenge. What are some of the things you have tried to do to get through to these students?
MJ	Thank you. What makes it hard to reach these students?
MJ	Okay, thank you. Now think of a good educational experience. It can be in school or outside of school but think of a time when you had an aha feeling, when everything fell into place. Maybe you could finally do something you had been struggling with or something finally makes sense to you. Maybe it was when your art teacher finally taught you how to mix paint and get primary colours or maybe it was when your mum or your dad taught to tie your shoelaces. So, whether it was inside of school or outside of school, think of a time that you had a really good educational experience. Can you briefly describe that to me?
MJ	Okay. Now think about what made that a good educational experience?
MJ	Okay. Thank you. In how many of your classes or lessons to you include the elements that you have just mentioned from the question?
MJ	Thank you. How do your students prepare for their goals for the future?
MJ	Okay. How do you plan to tap into students' interests?
MJ	Okay.
MJ	Okay. How do you sell to students that a mathematics course content is useful and important to them?
MJ	Thank you, XXX. What kinds of choices do you give students, if you do, and what kinds of decisions do you let them make?
MJ	Do you let them make decisions?

MJ	Okay. So, the last two questions. To what extent do you agree with the statement, first one, when it comes right down to it a teacher really can't do much because most of a student's motivation and performance depends on his or her home background?
MJ	Okay. Last question, to what extent do you agree with this statement: 'if I really try hard, I can get through to even the most difficult or unmotivated student? '
MJ	Thank you, XXX, for taking the time out for the interview.

Question	**Question type**	**Planned question**
1	**Initial opening question:** General, factual, quick, and establishes what is shared by each teacher	*You know I have been observing some of your students. What motivates these students?*
2	**Intermediate questions**: Introduces the topic and trigger conversation.	*a) Dealing with students who do not seem interested in education can be a real challenge. What are some of the things you have tried out to get these students through?* *b) Thinking about the students that are a challenge, what makes it hard to reach these students?*
3	**Ending questions**: Identifies most important aspects of the topic and ties up loose threads.	a) *How do you show to students that the mathematics course content is important to them and is useful?* *b) To what extent do you agree with this statement? When it comes right down to it, a teacher really cannot do much because most of a student's motivation and performance depends on his or her home background.* *a) To what extent do you agree with this statement then? If I really try hard, I can get through to even the most difficult or unmotivated student.*

APPENDIX J: THEMES, SUB-THEMES AND CATEGORIES LINKED TO JACOBS (2020) SEMISM

Theme	Sub-themes	Link to Jacobs (2020) SEMISM
Motivation	1.1: Pressurised Through Lots of Testing	*Meso Level* - Active engagement in mathematics could lead to enhanced student levels of motivation.
	1.2: Effectiveness in Fostering Students' Learning	*Exo and Meso levels* teacher characteristics (such as, commitment, caring, tolerance) supports the students learning and developing.
	1.3 Mathematics Applies to Real-Life	In the *Exo level* the linkages and processes between settings (home and school) need to support the real-life world of the students.
Active Engagement	2.1: Different Learning Styles	Inhibited factors such as ability, experience, knowledge, and skills development (*Micro level*) in the teaching and learning environment restricts conveyance and increase of knowledge and skills, leading to undesired outcomes. Therefore, teaching and learning could be teacher-centric, using direct teaching methods (*Exo level*) which is focused on the student and concentrate on the person or context characteristics and/or students' strengths
	2.2: Student Participation in Demonstration	In the *Exo level* new ideas about how, technology can improve learning and encourages implementation of the new ideas in the classroom could be built upon through pedagogical and subject content knowledge.
	2.3 Use of Videos, Library, or ICT Room	Jacobs (2020) SEMISM highlights in the *exo level* that it is very difficult for teachers to break out of their comfort zones and teach in new ways when they do not have sufficient practice with teaching mathematics using various media, such as technology. Therefore, through new CPD developments the teachers could 'up skill' themselves to enhance their own learning to benefit their students to be academically successful.
	2.4: Teacher Involvement	In the *Exo level* teacher routines, supported by parental involvement in schooling in turn promote effective attitudes and behaviour in the classroom, including higher engagement and improved performance by students.

Teacher Subject Knowledge	3.1: Teacher Inability	Interactions, linkages and processes between *Micro levels* that teachers have outside the school environment, including families, friends, and networks at the *Meso level* layer further add to complexity of how a teacher operates at the school *Micro level* with the student.
	3.2: Difficulty in Learning Mathematics	Learning and teaching is seen as equal determinants of the learning outcome. When the students are active participants in their learning, where optimal learning occurs through interactions that are bidirectional and reciprocal, teachers establish the basis for understanding students within their environment (*micro level)*.

APPENDIX K: TOPIC TEST DATA USED DURING INTERNAL TESTS

Surname	Forename	M/F	Tutor Group	SEN	FSM	End of KS3 Target Level	ar 7 sept 13	End of KS2 Level	Yr 7 Target	: Integers and Decimals Checkout	: Expressions and Formulae Checkout	1: Shape, Area and Volume Checkout	: Fractions, Dec, perc Checkout	rm 1 Test (N1, A1, M1, N2)	ocolate Box Assignment	: Statistics Checkout	atistics Project	: Sequences Checkout	: Calculations and Measures Checkout	rm 2 Test (S1, A2, N3)	: Constructions and Angles Checkout	gles in Polygons Investigation	: Probability Checkout	: Equations and Graphs Checkout	aphical Calculator Investigation	: Transformations Checkout	ssellations Assignment	rm 3 Test (All units)
					N	7c	A2	5c	5a	6b	5a	6c	6b	6b	6a	6b	6c	6c	7c	7c	6a	6a	6c	6c	6b	6c	6c	6c
					Y	7b	A2	5b	6c	6c	6b	6a	6a	6a	6b	6b	6c	6c	6c	7c	7c	7b	7c	7c	6c	7c	7c	6b
				N	N	8b	B1	6b	7c	6a	6c	7c	6b	6b	6c	6c	6c	7c	7c	6b	6b	6a	6a	6a	7c	6c	6c	6a
				N	N	7a	B1	5a	6b	7c	6b	7c	6c	6b	6b	6a	6b	6c	6c	7c	7c	6a	6a	6c	6c	6b	6b	6c
				N	N	7a	B1	5a	6b	6b	6b	6a	6a	6a	6a	6b	6b	6c	6c	6c	7c	7c	7b	7c	7c	6c	6c	6b
				N	N	7b	B1	5b	6c	6b	6b	6a	6b	6c	7c	7c	7c	7c	7c	6b	6b	6b	6a	6a	6a	7c	7c	6a

Surname	Forename	F	tor Group	N Status	M	L	d of KS3 Target	T Sept 13	d of KS2 Level	Yr 7 Target	: Integers and Decimals Checkout	: Sequences Checkout	: Area and Angles Checkout	ntominoes Assignment	: Frac, Dec, Perc Checkout	m 1 Test (N1, A1, M1, N2)	Statistics Checkout	dangered Animals Assignment	: Expressions and Formulae Checkout	ner Party Assignment	: Calculations and Measure Checkout	m 2 Test (S1, A2, N3)	Probability Checkout	: Shape and constructions Checkout	king Muffins Assignment	: Equations and Graphs Checkout	: Transformations Checkout	m 3 Test (All units)
							6b	B4	4b	5c	5a	5a	4a	4a	4c	5c	4b	4c	5c	5c	4b	4b	4c	4c	4b	4b	4c	4b
							6c	B4	4c	4a	4b	5c	5c	5c	5c	4b	4b	4c	4c	4c	4b	4c	4a	4a	4a	5c	5c	5c
							6c	B4	4c	4a	4a	5a	5b	5c	5b	5c	5c	5b	5a	4a	4a	4a	4c	4c	4c	4b	4c	5c
							6c	B4	4c	4a	4a	5c	5b	5b	5c	5c	4a	4b	4b	4b	4a	4a	4a	5c	5c	5b	5b	5b

Surname	Forename	M/F	Tutor Group	SEN Status	FSM	EAL	End of KS3 Target	SET Sept 13	End of KS2 Level	Yr 7 Target	N1: Integers and Decimals Checkout	A1: Sequences Checkout	What's my rule assignment	M1: Measures Checkout	How big is the school assignment	Term 1 Test (N1, A1, M1)	N2: Frac, Dec, Perc Checkout	S1: Representing Data Checkout	Statistics Project	N3: Calcs & Measure Checkout	Term 2 Test (N2, S1, N3)	S2: Probability Checkout	M2: Angles and Shape Checkout	A3: Integers and Graphs Checkout	M3: Trans & Symmetry Checkout	Symmetry Assignment	S2: Averages Checkout	Term 3 Test (All units)
				N	N		5b	A5	3b	4c	4c	4c	4a	4c	4a	4b	4c	4a	4a	4b	4c	4a	4c	4a	4b	4c	4a	4a
				S	N		5c	A5	B	3a	4c	4c	4b	3a	A	4c	4c	4a	A	4c	4c	4a	3a	A	4c	4c	4a	4c
				A	N		5a	A5	3a	4b	4c	4b	4a	3a	4a	4c	4b	3a	4a	4c	4b	4c	4a	4a	4b	4c	4a	4a
				A	N	N	5a	A5	3a	4b	4c	4c	4a	4c	4a	3a	4a	4b	4b	3a	4c	4c	4a	3a	4c	4c	4a	4b

APPENDIX L: EXAMPLES OF QUESTIONS USED- STUDENTS NEEDED TO SHOW WORKING

Answer ALL questions.

Write your answers in the spaces provided.

You must write down all the stages in your working.

5 Thais has a large bottle of shampoo.
There are 2 litres of shampoo in the large bottle. 2000 ml.

Thais also has some empty small bottles.
Each small bottle can be completely filled with 150 m*l* of shampoo.

How many small bottles can be completely filled with shampoo from the large bottle?

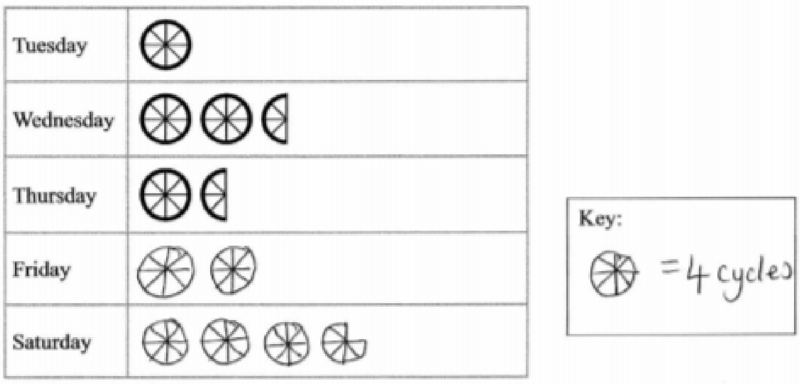
150 ml = 1 bottle
300 ml = 2 bottles
600 ml = 4 bottles
1200 ml = 8 bottles
1800 ml = 12 bottles
1950 ml = 13 bottles

$\frac{2000}{150} = 13.\dot{3}$

13

(Total for Question 5 is 3 marks)

6 The incomplete pictogram shows information about the number of cycles sold in a shop on Tuesday, on Wednesday and on Thursday.



A total of 20 cycles were sold on Tuesday, Wednesday and Thursday.

8 cycles were sold on Friday.
15 cycles were sold on Saturday.

Use this information to complete the pictogram.

5 ⊛ = 20
⊛ = 4 CYCLES

(Total for Question 6 is 3 marks)

APPENDIX M: INTERVENTION CAMP SCHEDULE

Maths and English Revision Programme:

Friday 11 – Sunday 13 March 2016

Outline of weekend:

Friday 11 March 2016	***Leave school at 3pm*** 17h30 • Arrive at Calshot • Friday meal at 18:00	***19:00 – 20:30*** 19:00 – 19:45 Maths Revision or English Revision 19:45 – 20:30 Maths Revision or English Revision	
Saturday 12 March 2016	***Breakfast 8am*** 9:30 Group A Revision (10-Ma) 1h05 9:30 Group B Revision (10-Eng) 9:30 Group C Revision **(10- climb and high Ropes)**	10:35 Group A Revision (10-Eng) 1h 05 10:35 Group B Revision ((10-Ma) 10:35 Group C Group C **(10- climb and high Ropes)**	11:35 Group A Revision (10-Ma) 1h 05 11:35 Group B Revision (10- Eng) 11:35 Group C (**10- climb and high Ropes**)
	12:45 – 13: 45 LUNCH	**12:45 – 13: 45 LUNCH**	**12:45 – 13: 45 LUNCH**
	13:45 Group B (**10- climb and high Ropes)** 13:45 Group A Revision (10-Eng) 1h05 13:45 Group C Revision (10 – Ma)	13:45 Group B **(10- climb and high Ropes)** 13:45 Group A Revision ((10-Ma) 1h05 13:45 Group C Group C Revision (10 – Eng)	13:45 Group B (**10- climb and high Ropes)** 13:45 Group A Revision (10 Eng) 1h 05 13:45 Group C Revision (10 – Ma)
	18:00 – 19:00 DINNER	**18:00 – 19:00 DINNER**	**18:00 – 19:00 DINNER**
Past Paper Questions and Evening Entertainment	19:15 – 20:30 Group A 1h 15 19:15 – 20:30 Group B 19:15 – 20:30 Group C	19:15 – 20:30 Group A 19:15 – 20:30 Group B 19:15 – 20:30 Group C	19:15 – 20:30 Group A 19:15 – 20:30 Group B 19:15 – 20:30 Group C
Sunday 16th March 2016 ***Breakfast 8am***	9:30 Group B Revision (10-Ma) 9:30 Group A **(10- climb and high Ropes)** 9:30 Group C Revision (10-Eng)	10:35 Group B Revision (10-Eng) 10:35 Group A (**10- climb and high Ropes)** 10:35 Group C Revision (10- Ma)	11:35 Group B Revision (10-Ma) 11:35 Group A **(10- climb and high Ropes**) 11:35 Group C (10 – Eng)
	12:45 – 13: 45 LUNCH	**12:45 – 13: 45 LUNCH**	**12:45 – 13: 45 LUNCH**
	13:45 - 14:45 Group A Revision (Ma) 13:45 - 14:45 Group B (Eng)	13:45 – 14:45 Group A Revision (Eng) 13:45 – 14: 45 Group B (Ma)	13:45 – 14:45 Group A Revision (Ma) 13:45 – 14:45 Group B **(climb and high Ropes**)
	15:00 DEPARTURE	**15:00 DEPARTURE**	**15:00 DEPARTURE**